Industrial QUALITY CONTROL

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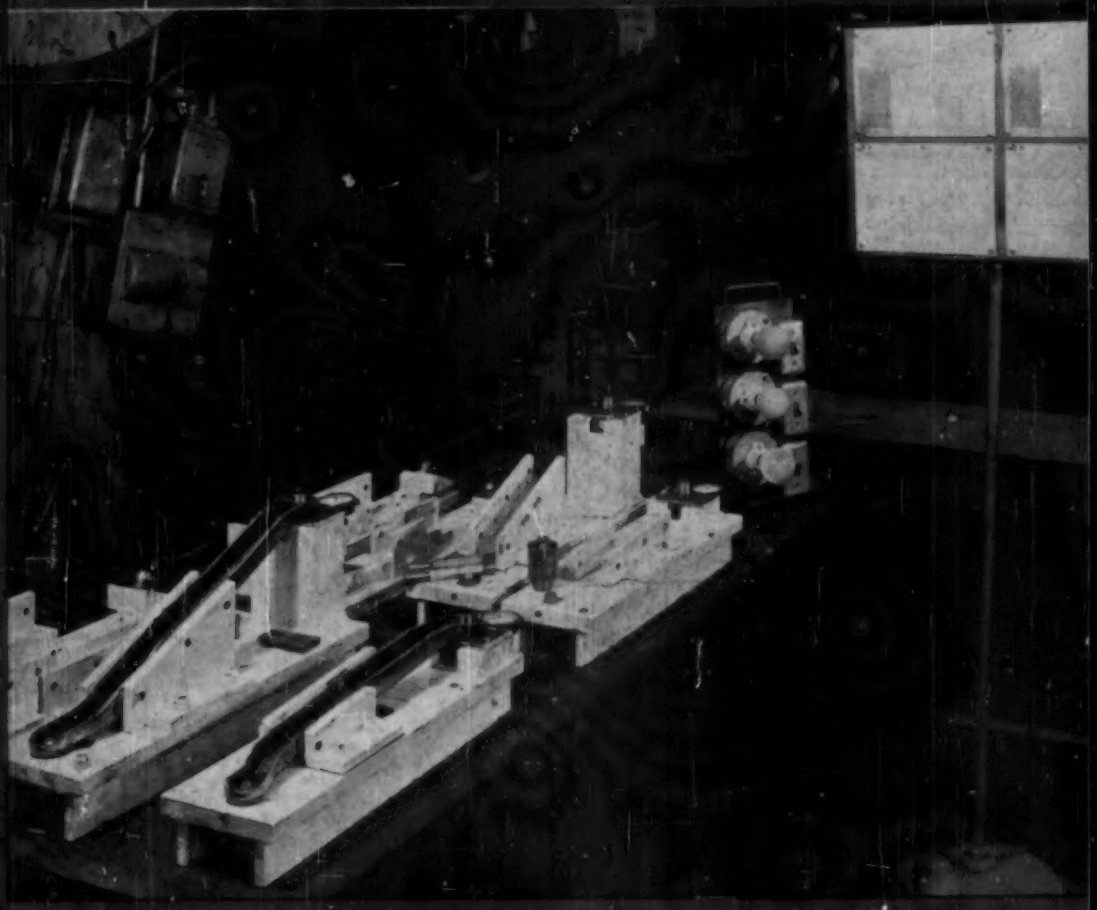

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Statistical Methods

1946—TENTH ANNIVERSARY YEAR—1956

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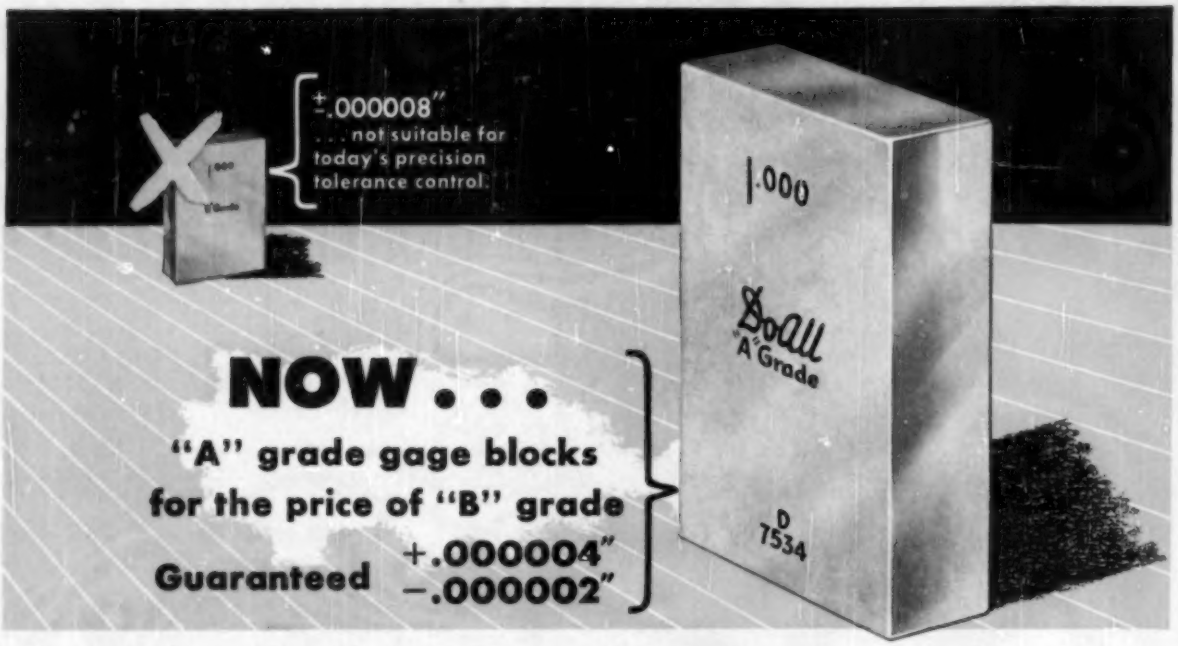

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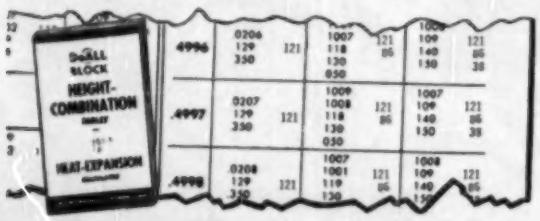

dimension of 2.4977 (± .0001") a minimum of five blocks from an 86 piece set would be required. Assuming the most favorable combination—one two-inch block and four others—the stack *could* vary plus or minus .000064" (over a half-tenth). This is more than half the allowable tolerance of the part itself! If some of the individual blocks were plus and some minus, the total error would be less—but how much less?

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OUR COVER

This month's cover illustrates how product quality is maintained by use of a light system. A detailed description is contained in L. S. Eichelberger's article, "Statistical quality control in a press shop" which appears on page 12.

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Establishing Control of Tire Cord Testing Laboratories*

FRANK AKUTOWICZ, H. MACK TRUAX

American Viscose Corp., Marcus Hook, Pa.

Introduction

This article describes an experiment whose purpose was to discover a method for maintaining control of several tire cord testing laboratories within the company. Some of the laboratories were themselves control laboratories for tire cord mills in different parts of the United States. Five laboratories were thus involved in measuring certain mechanical properties of tire cord, which, for the purpose of this discussion, can be taken as breaking strength as measured by a suitably standardized test.

The behavior of the laboratories within the group can be summarized very briefly: they fluctuate. Consequently certain questions which could reasonably be asked had, on occasion, only ambiguous and unsatisfactory answers. For example, a group of bobbins tested by the laboratories in turn, round robin style, would establish trends, or what looked like trends, which subsequent rounds would wipe out and re-establish in different form. Were the trends real? Was it laboratories or samples which were different on subsequent rounds?

Persons familiar with control testing of the cord know of many sources of variability which contribute to the scatter in the results of a group of tests. The testing machines commonly used, being mechanical force-measuring devices, are subject to rubbing and rolling frictions of a random character. The machines are calibrated indirectly using static masses with static or semi-static frictions present, while in actual operation the machines measure changing forces with dynamic frictions present. Thus the calibrating procedure has a random error which is not small (compared to the forces measured) and which is not easy to detect.

If the machines could be calibrated with a standard sample of known strength, the variability due to calibration could be eliminated. However, in practice this introduces several new components of variability: the strength of a material, any material, is a random quantity. The strength of a bobbin of tire cord varies with adjacent breaks as well as with more widely separated breaks. It also varies from bobbin to bobbin. Other, unidentified, components of variability are also present. It is with such blunt and uncertain tools that variation among laboratories is to be sought out, identified, and if possible, controlled.

The basic element for controlling variation among laboratories is the sample with known properties. Part of the sample is given to each of the laboratories, and they test some of it every day. Deviations recorded by a laboratory give it an immediate indication of what adjustments are needed in the testing machines.

The Experiment

The experiment described in this article had as an objective the quantitative study of the nature of the variability present in bobbins of tire cord. This experiment was preliminary to obtaining the sample with known properties. In fact, based on this experiment, a method was inferred for drawing a sample whose properties were measured, and hence constituted the sought for sample with known properties.

The experiment, a balanced, mixed-model factorial design, was quite simple and could be performed in a few days. Only an hour or so is needed to analyze the data obtained. The plan of the experiment is as follows: sixteen bobbins in two sets of eight were examined in all. The two sets were random selections from regular production at two different plants, each of which was making cord by a different process. The cords were nominally the same and had the same end uses. Cords from different processes were used to broaden the base of the experiment, i.e. conclusions to be obtained would apply to radically different processes. Breaks were made in adjacent pairs at 500 yard intervals over the length of each bobbin. A single machine at a single laboratory was used for all the breaks, which were completed in a single uninterrupted session. Table I shows the data obtained in this way. The strengths have been coded as shown to simplify the subsequent analysis.

Analysis

The first step in the analysis is to write down the mathematical model which is presumed to describe the data. The ingredients of the model are shown in Table II. The model is called a mixed model because it contains a mixture of random variables

*Presented at ASQC Textile Conference, January 29, 1955. Clemson, S. C.

TABLE I—Coded Raw Data

		0 Yds.		500 Yds.		1000 Yds.		1500 Yds.		2000 Yds.		2500 Yds	
	Adjacent Breaks	1	2	1	2	1	2	1	2	1	2	1	2
Plant I	Bobbin 1	-1	-5	-2	-8	-2	3	-3	-4	0	-1	-12	4
	2	1	10	1	2	2	2	10	-4	-4	3	4	8
	3	2	-3	5	-5	1	-1	-6	1	2	5	7	5
	4	6	10	1	5	0	5	-2	-2	1	1	5	9
	5	-1	-8	5	-10	1	-5	1	-4	5	-5	3	6
	6	-1	-10	-6	-8	-2	2	0	-3	-8	-1	-2	-4
	7	-9	-2	5	-2	7	-2	-2	-2	-1	2	10	5
	8	0	2	-5	-2	5	3	10	-1	4	1	7	-1
Plant II	Bobbin 1	10	8	-5	6	2	13	7	15	17	14	18	11
	2	9	12	6	15	15	12	18	16	13	10	9	11
	3	0	8	12	6	2	0	5	4	18	8	6	8
	4	5	9	2	19	15	5	21	18	15	11	18	15
	5	-1	-1	11	19	12	10	1	20	13	9	4	6
	6	7	16	15	11	12	12	8	12	22	11	12	21
	7	-5	1	-2	10	12	15	2	13	10	10	7	5
	8	10	9	10	15	9	16	12	11	18	20	11	15

The numbers are 1/10 lb. deflections from 21.5 lb.

and fixed parameters, the α's and the a's respectively. Writing down the model equation is considerably more than a departure into heavy formalism. The model performs two essential operations: (1.) it enables one to partition and calculate the various sums of squares with great ease, (2.) after the sums of squares and mean squares are calculated it enables one to form the proper F-ratios, also with great ease. Our purpose here is not to justify and explain the analysis of variance performed on this experimental data, but to illustrate the type of industrial research problem which can be handled by the method.* The analysis of variance is shown in Table III.

TABLE III

Source of Variance	d. f.	SS	MS	EVMS
B	14	1230	88*	$12\,\sigma^2_B + 2\,\sigma^2_{BM} + \sigma^2_N$
M	5	493	99*	$32\,\sigma'^2_M + 2\,\sigma^2_{BM} + \sigma^2_N$
N	96	2091	22	σ^2_N
P	1	4741	4741*	$96\,\sigma'^2_P + 12\,\sigma^2_B + 2\,\sigma^2_{BM} + \sigma^2_N$
BM	70	1579	23	$2\,\sigma^2_{BM} + \sigma^2_N$
MP	5	278	56	$16\,\sigma'^2_{MP} + 2\,\sigma^2_{BM} + \sigma^2_N$
	191			

Interpretation

The large mean square assigned to the two different plants arises because the mean cord strengths made by the two different processes differ by a pound. There is no evidence, however, that the variability is different for the two processes. The two processes could have different variability in three different ways. (1.) From bobbin to bobbin. The fourteen degrees of freedom in the bobbin mean square are made up of seven from each process. These could be compared with each other, although the test is not very sharp. Bobbin sums have the same range in each process. (2.) The systematic variation of strength with length could be different for the two processes. If so, the MP interaction mean square would be a measure of this difference. But the MP mean square does not differ significantly from its estimated error variance, which is the BM mean square. (3.) The variability between adjacent breaks could be different for the two processes. This can be checked by partitioning the 96 df for the N sum of squares into its two 48 df components identified with each process and comparing them with each other. The 48 ranges for each process sum up to equal values.

The spacing mean square, giving a measure of systematic variability, turns out to be significant (½ percent level) by F test. The sum of squares, 493, has 5 df of which the linear component accounts for 457. Accordingly, a straight line is a proper representation of the systematic variation of strength with length along a bobbin. The equation (apart from an additive constant which differs for the two plants) is Strength, lbs. = 0.00018d, where d is the distance in yards from the outside of a bobbin. Thus the standard 3000 yard bobbins are ½ lb. stronger on the inside than they are on the outside. (For 2 ply 12×12 cords).

TABLE II—ANOVA

Source of Variance	Abbrev.	Subscript	Symbol	Model	No. of Levels
Bobbin	B	i	$a^B_{i\cdot}$	II	8
Spacing	M	k	α^M_k	I	6
Adjacent Pos.	N	j	$a^N_{ijk\cdot}$	II	2
Plant	P	s	α^P_s	I	2

Model Equation: $X_{ijks} = \mu + a^B_{i\cdot} + a^N_{ijk\cdot} + \alpha^M_k + \alpha^P_s + a^{BM}_{ik\cdot} + \alpha^{MP}_{ks}$

The Model I terms are fixed parameters whose values are to be estimated from the data. Model II terms are random variables whose scatter is to be estimated from the data.

The random variability has two components: between bobbins σ^2_B, and between adjacent breaks, σ^2_N. These are both estimated from Table III.

$$\hat{\sigma}^2_N = 0.22$$

$$\hat{\sigma}^2_B = \frac{88-23}{12(100)} = 0.054$$

These estimates are not regarded as hard facts, although $\hat{\sigma}^2_N$ is known with fair precision. They serve rather as a basis for drawing a further sample on which confirming measurements can be made. But using these estimates, the variance of the average of twenty breaks made at adjacent positions on ten bobbins is estimated to be

$$\hat{\sigma}^2_{\bar{X}} = \frac{0.22}{20} + \frac{0.054}{10} = 0.016$$

from which

$$\hat{\sigma}_{\bar{X}} = \sqrt{0.016} = 0.13 \text{ lb.}$$

The 3 $\sigma_{\bar{X}}$ limits then serve as a daily check on the calibration of the machines. If the average of the twenty breaks deviates by more than ⅜ lb. from the previously established mean, adjustments are needed on the machine. Making 20 breaks is a much faster operation than the conventional indirect calibration using dead weights. It also leads to a direct conclusion regarding the accuracy of calibration of the machines.

Accordingly, a larger sample of bobbins from a given process was tested at a given laboratory by making two adjacent breaks on the outside of each bobbin in a single uninterrupted session of testing. Fresh estimates of σ^2_B and σ^2_N were computed The daily procedure at each laboratory was then set at two breaks on each of five bobbins. There is enough cord on the bobbins to last about seven years so that the slow growth of strength as the bobbins are used can be ignored for the first year or so. But then the samples are changed every year so that they continue to resemble current production. The system has been in operation about a year now and is being extended to other textile yarns as well.

It should be pointed out that this is a scheme for controlling the variability between laboratories or, for that matter, between single machines within a laboratory. As such, it does not provide a control of the absolute level as a whole. If the designated standard machine was out of calibration when the composite sample was tested, then all the laboratories will be stabilized at the wrong level. An absolute calibration of the standard machine cannot be achieved by repeated testing.

Acknowledgement

We wish to acknowledge the assistance of Mr. C. Daniel, Consulting Engineering Statistician, New York, N.Y., in the statistical part of this experiment.

*A succinct discussion of the general case is given by Scheffé in the April, 1954 issue of *Chemical Engineering Progress*. Scheffé's notation is used in this article.

Quality Control of Tubular Steel Products

W. T. ROGERS

National Tube Div., U. S. Steel Corp., Lorain, Ohio

Introduction

While this article is primarily concerned with quality control and tubular products made from steel, it is pointed out that the subject matter is applicable to quality control in basic industry generally and the material presented pertains equally as well to copper, brass, lead, glass, or an end product for customer consumption of any of the large industries which procure their own raw materials and perform all intermediate manufacturing steps. The title "quality control" may in itself appear restrictive in that it tends to limit the concept of the material herein presented to the accepted association of quality control with the use of control charts in conjunction with some form of sample inspection. These are useful tools and in all probability the main tools in any quality control organization, but in a basic industry such as a steel plant they must be supplemented by at least three other branches of statistical procedure, namely correlation analysis, experimental evaluation, and testing for significance.

It is not the purpose of this article to criticize or to minimize the relative value of any statistical quality control procedure, but it is of importance to note that the concept of acceptance sampling of finished product for dimensional and visual defects has not been accepted generally by steel manufacturers or consumers. This does not mean that the use of sampling inspection is not appreciated because there are many instances of quality evaluation with reference to chemical, physical, and metallurgical characteristics which require some form of sample inspection. In addition, there are many points throughout the manufacturing process where quality is evaluated by means of periodic sampling procedures. These applications are continually being studied and applied by the majority of progressive steel plant operators.

It may be stated then, that there are two generally accepted concepts of statistical quality control, one of which is concerned only with acceptance-rejection sampling, and the other with control of the entire process which takes in almost the entire field of statistical methods. This second concept is the one that must be embraced in the quality control program of any large industry.

SQC Activity at Lorain Works of National Tube

In order to project a clearer picture of the scope of activity associated with such a program it is necessary to sketch briefly the size and activity of the organization within which it is required to function. Lorain Works, of National Tube Div., United States Steel Corp., employs approximately 12,000 people and produces in the neighborhood of 100,000 tons of buttweld and seamless pipe per month. The plant consists of a coke plant, docks and raw material storage facilities, five blast furnaces, 12 open-hearth furnaces, three bessemer converters, rolling mill and semi-finished product conditioning facilities together with buttweld and seamless pipe producing units.

The statistical quality control activity may be classified in three sub-divisions all of which are integrated into the one common purpose of maintaining and improving the quality of finished products. These are as follows:

Process Control

Process Investigation

Process and Product Improvement

Process control is a routine procedure which consists of following those factors in each phase of production which have been found from past experience to be associated with the occurrence of unsuitable material. This part of the quality control program is supported by a system of statistical control charts pertaining to each department in the production system. This application makes it possible to keep each department head advised with respect to deviations from normal practice which are likely to result in higher than normal rejects at some subsequent processing point. Process control with respect to dimensional characteristics is a function of inspection and is likewise set up on a basis which lends itself to control chart analysis.

The second sub-division, process investigation, is a necessary adjunct of the quality control organization. This phase of the work consists of analyzing processing data for causes of abnormal departures from the limits established for any of the quality factors under observation. In statistical terminology this can be defined as the determination of "assignable causes." In most instances this is not a difficult task. However, there are times when extensive analytical work is required which the statistical quality control division is implemented to perform.

The third function of the statistical quality control group is to aid in the evaluation of changes in processing procedure and the development of new or improved products and processes. One of the accepted functions of management is the responsibility for improving practices in order to improve quality, increase production, and lower costs. In the highly complex business of steel production and fabrication each process has a multiplicity of factors related to these three objectives. It is therefore necessary to have some means of evaluation which will permit comparisons to be made on an equitable basis. These means are available in the various statistical techniques of correlation analysis, significance tests, and analysis of variance, and for this reason are a part of the statistical division's responsibility.

As in most steel plants, the statistical quality control group operates as a division of the metallurgical department and is directly responsible to the chief metallurgist at Lorain. It is staffed with four people; a statistical engineer with the status of supervisor, an assistant statistician, a junior statistician, and a statistical clerk. The statistical engineer has a thorough knowledge of statistical procedures together with a broad background of mill experience. The assistant statistician has a working knowledge of statistical methods and extensive experience in the preparation of various statistical summaries and reports. The junior statistician is the coordinator between the accounting department, tabulating bureau and the statistical division and has a working knowledge of tabulating equipment and the preparation of tabulating reports and summaries. The statistical clerk receives and prepares incoming data for purposes of routine daily reports used in presenting daily quality control information to management.

The statistical division of the metallurgical department serves as a clearing center for quality control and product yield information among the operating, inspection, accounting, and metallurgical departments with the chief metallurgist making simultaneous reports with respect to abnormal conditions and recommended corrective action to top management and the operating departments.

SQC Procedures

The quality control procedures consist of the following operations:

1. Collection of data
2. Processing of data
3. Reporting quality control information to management
4. Maintaining quality control charts
5. Determination of assignable causes for abnormal conditions
6. Study of methods and practices for quality improvement

The collection of data is accomplished by the use of existing routine reports made out by metallurgical observers, chemical laboratory personnel, mill accounting clerks and the inspection deparement. Information is compiled on forms suitable to the purposes of all interested parties so that duplication of effort is avoided. Procedures are set up whereby the required reports are channeled through the statistical division. Practically all quality related data are punched on tabulating cards and wherever possible are collected in such a manner that they need only a minimum of checking in order to prepare them for the tabulating bureau. Eleven cards are punched for each heat of steel produced so that the entire history of the heat with respect to quality related factors is available on these cards.

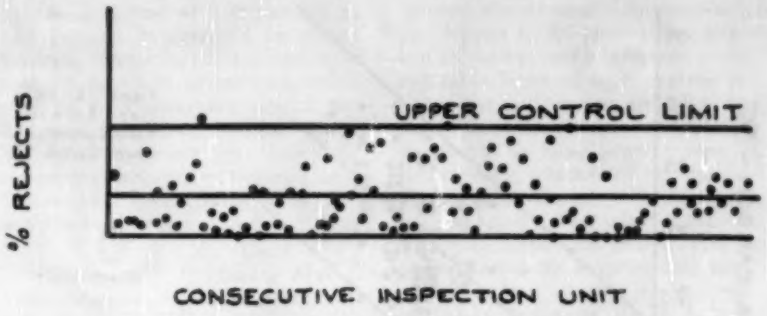

Figure 1—Control Chart for Inspection Rejects

The spark plug of the program is a daily quality control letter. This letter, which is forwarded to top management each day, contains a summary of inspection rejects for the preceding 24 hour period together with an indication of the state of control of each type of reject by class of material and producing unit. In addition, this letter also presents a condensed summary of quality related factors in each processing department with particular attention being called to those variables which show abnormal departures from the desired level of control. In addition to the daily quality letter, a summary of quality variables is prepared each week showing the comparative status of these variables for the current week, the preceding week, and the most recent six months average. This is followed by a monthly summary which is prepared for discussion at a regular monthly steel quality committee meeting. This committee is composed of the various production department heads of the entire plant, the chief metallurgist, and superintendent of inspection.

The statistical division also maintains a set of some 200 control charts of which 20 are concerned with following the level of inspection rejects at various inspection locations throughout the plant. The remaining charts have the purpose of maintaining a check on the state of control of numerous quality related variables throughout the entire processing procedure. Figure 1 is an example of one such chart for following of the control of rejects and Fig. 2 is a chart for a quality related variable.

The determination of assignable causes for departures from normal is also a function of the statistical group. Each heat of open-hearth and bessemer steel is identified from the start of its manufacture until the final inspection is completed and inspection results are summarized daily. When the daily average percent rejects exceeds the established upper control limit, the inspection results are examined in detail to determine the causes. When definitely assignable causes are found

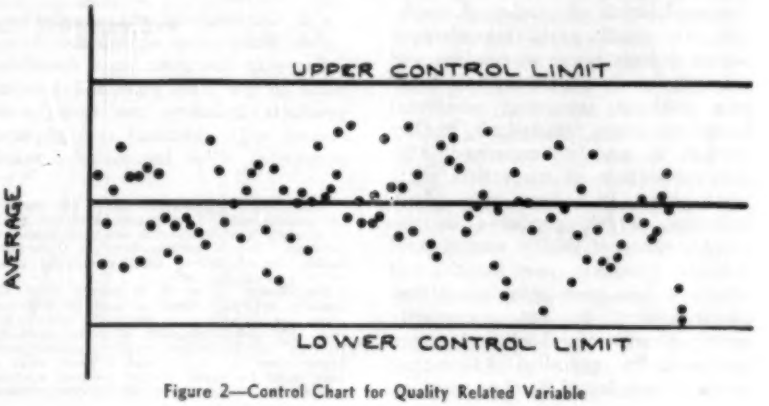

Figure 2—Control Chart for Quality Related Variable

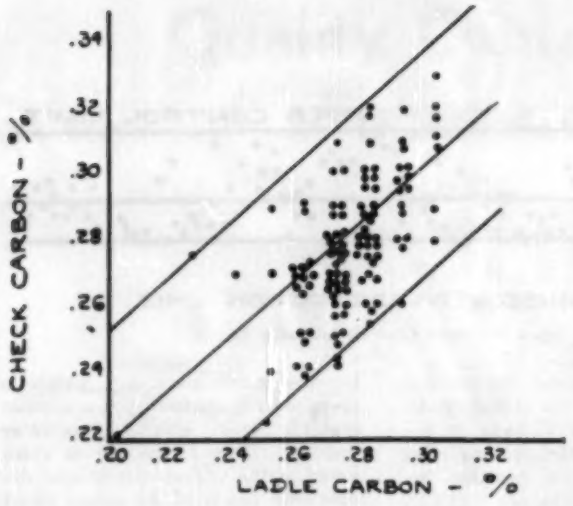

Figure 3—Relation Between Ladle Carbon and Check Carbon

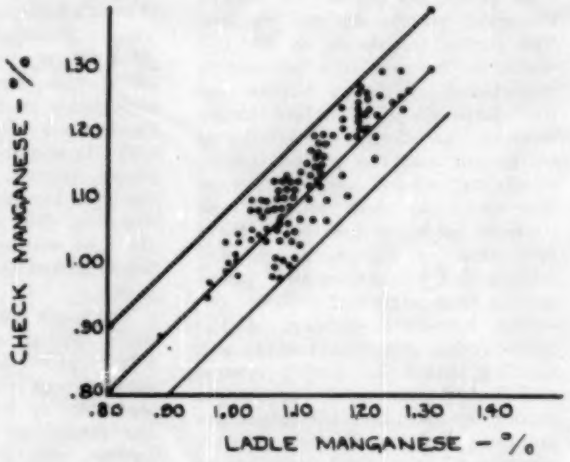

Figure 4—Relation Between Ladle Manganese and Check Manganese

they are called to the attention of the processing department in which they occurred so that the department head may be apprised of the necessity for constant surveillance of factors within the processing area which contribute to the occurrence of inspection rejects.

In addition to its quality related functions, the statistical division also makes many special studies which could properly be classified as statistical research and which are concerned with the use of new practices and materials as they are related to quality and production rates. This function comprises a major proportion of the work load and is looked upon as equal in importance with the other statistical activities.

The basic approach to quality control of steel products is no different in the large steel plant than in the small metal fabricating shop. The same three steps of specification, production, and inspection apply here as in any other manufacturing activity. These three phases of quality control, while of similar importance in any industry, require a different approach with respect to the application of statistical methods. In small parts manufacture where defects occur at random and it is possible to secure random samples without incurring abnormal handling costs, statistical quality control is mainly concerned with the application of inspection sampling plans. In a large steel plant, however, which produces in the neighborhood of 100,000 tons of steel tubular products per month and where it has been established that abnormalities do not necessarily occur at random and where it is not economically practical to secure random samples of finished product, the statistical quality control approach must be different.* The problem is to control the various processing practices so that a minimum proportion of rejectable material will be delivered to the inspection areas.

Problems in Quality Control in Steel Pipe and Tube Manufacture

The problem of quality control in the manufacture of steel pipe and tubes can be classified under three headings as follows:

1. Chemical and physical properties
2. Dimensional characteristics
3. Elimination of defects

Some of the most rigid specifications in the line pipe and tubular products industry are those concerned with chemical and physical properties. The increased demand for higher strength material to support higher working pressures together with the chemical limitations imposed by present day welding practices require exceptionally close control of chemistry particularly with respect to carbon and manganese. The emphasis placed on this phase of quality control is not generally realized. It is a problem, however, in which statistical relationships and probability analysis have played an important part. For example let it be assumed that 0.33 percent maximum carbon and 1.30 percent maximum manganese on finished product have been specified together with a physical property which requires working to the top limit of both these elements. In steel making as in any other repetitive manufacturing process, no two heats are exactly identical in their chemical composition and so when working to a maximum specification limit it is necessary to aim for an average which will take the normal variability into consideration. The first samples for the determination of chemistry are taken from the molten metal as it is being poured from a large ladle into a series of ingot molds. At this point, the steel is in its most homogeneous state. Once the metal starts to solidify the physical laws of solidification and segregation tend to reduce the uniformity of distribution of chemical constituents so that any subsequent analysis is likely to vary somewhat from that of the original ladle tests.

It is apparent from the foregoing brief explanation that a knowledge of the relation of the chemistry of the molten metal, or what is known as ladle analysis in the steel industry, to that of finished product, or check analysis, plus the variability

*Ed. *Note:* In the strict sense the statistical quality control procedure does not apply if quality measurements are not made at random. Where randomizing is a limiting factor the statistical quality control chart sensitivity is reduced.

Mr. Rogers intends to imply that the quality control approach must be different since statistical quality control is uneconomical. If biased sampling is to be used for control, the statistical quality control technique does not apply and a great deal of care must be given to the method adopted and to the interpretation of the control data.

from heat to heat of steel, is essential in order to set up working limits which will meet the limitations of the customer's specification. This relation for carbon and manganese is present in Figures 3 and 4, respectively. In Fig. 3 it will be noted that with a range of 0.24 percent to 0.30 percent ladle carbon, the check carbon varied from 0.23 percent to 0.33 percent and not until ladle carbons of 0.30 percent are reached is there a possibility of exceeding 0.33 percent carbon on check analysis. It is therefore evident that a working practice which is unlikely to produce ladle carbon in excess of 0.30 percent will satisfy the customer's requirements. The range of 0.24 percent to 0.30 on ladle carbon indicates a standard deviation of 0.01 percent carbon which, with a normal distribution, makes it logical to assume that the aimed for carbon should be 0.27 percent or 0.30 percent minus 3σ in order that practically no heats will exceed the specification maximum.

Figure 4 presents similar information with respect to manganese showing that with a range of 0.88 percent to 1.25 percent ladle manganese, a spread of 0.89 percent to 1.30 percent is obtained on check analysis, indicating that to produce nothing over 1.30 percent on check analysis it is necessary to aim for 1.07 percent or 1.25 percent minus 3σ. On this basis the following comparison between customer specification and steel making aimed for analysis is obtained.

Customers Specification	Steel Making Aim Specification
0.33 max carbon	0.27 average carbon
1.30 max manganese	1.07 average manganese

The result of the application of this type of control is shown in Figures 5 and 6, where frequency distributions of check analysis are super-imposed on distributions of ladle analysis for both carbon and manganese indicating that the type of control expected was obtained.

Steel pipe and tubular products like other formed metal products are made to relatively close dimensional tolerances for such things as length, outside and inside diameter, weight per foot and wall thickness. These dimensional characteristics are subject to 100 percent inspection but in a great many instances a considerable lapse of time expires between the last forming operation and final inspection. It is therefore necessary to have some means of determining whether or not material being produced will meet the desired specification when it reaches the final inspection point. This is accomplished by a systematic sample inspection of the product immediately following the final production operation. By applying closer control than is actually required by the specification it is assured that finished product inspection will find practically all material well within the required specification tolerances.

Figure 7 is a control chart of groups of four measurements taken each hour on one of these dimensional characteristics. This chart indicates the statistical limits within which the material was produced together with the specification limits within which it could theoretically be produced and still have the total product within the acceptance limits. Figure 8 is a frequency distribution of this dimension on the entire lot represented by the Fig. 7 control chart which shows that all material inspected conformed to the specification requirements.

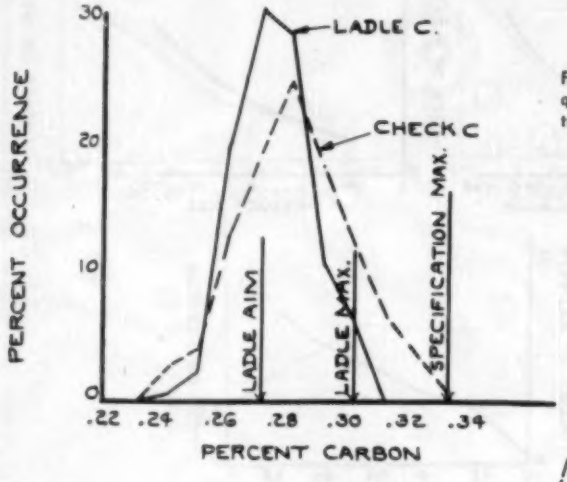

Figure 5—Frequency Distribution of Carbon

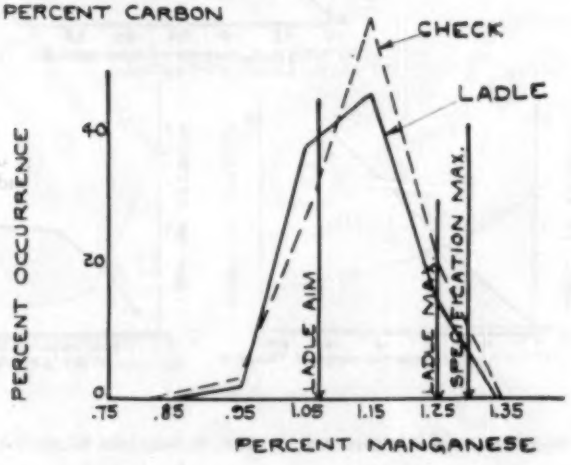

Figure 6—Frequency Distribution of Manganese

Multiple Correlation Analysis

The third phase of the statistical quality control program is that of investigating and studying various processing practices and procedures with respect to factors associated with the occurrence of defects in semi-finished and final product. In addition to the routine observance for the purpose of recognizing abnormal reject levels and the assignable causes for such conditions, effort is constantly being made to reduce the normal level of rejects. The statistical method used in this type of research is mainly multiple correlation analysis. It is realized that this method, like others, has its limitations but it has proved over a long period of time to be the most versatile, the easiest taught to non-technical personnel, the best adapted to punch card procedures, and the simplest to interpret to operating personnel of the various multiple factor analysis methods available. The use of this method as applied to a typical research problem is presented in the following example.

In the production of large seamless steel pipe, the first inspection opportunity is presented when the steel comes off the rolling mill in

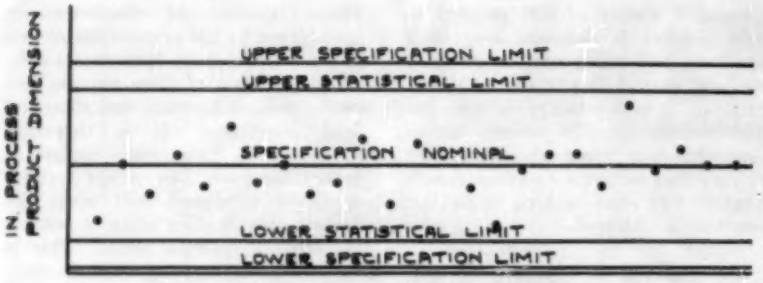

Figure 7—Control Chart for Dimensional Characteristic

the form of a round billet. In general, the round billets are delivered to a peeling machine which takes a predetermined cut from the entire surface. This operation removes all minor surface defects and produces a surface on which more serious defects are readily discernible. The inspection personnel then decide which billets should be rejected as not suitable for further processing and which billets should be subjected to further conditioning. It is therefore evident that close attention to quality should be centered on this operation and effort is constantly being applied to reduce the percentage of material rejected at this point. This type of quality control therefore requires an extensive knowledge of the relation of processing variables to the occurrence of rejects.

One of the most important steps in this type of problem is the original approach. It is not a good practice for the variables included to be selected indiscriminately. The first step, therefore, is a detailed discussion of the problem with all interested parties. In this case, the approach to the problem was discussed with operating, inspection, and metallurgical personnel. As a result of this preliminary consultation it was decided that 31 factors should be examined with respect to their association with the occurrence of rejects. A period was then selected from an examination of the routine control charts during which abnormally high and abnormally low occurrences of rejects were observed. During the period chosen approximately 2300 open-hearth heats of steel of 160 ingot tons each were processed through this particular inspection area. Data collection was not a problem as the routine tabulating procedure employed kept all data on the various punched cards which were prepared daily. Card preparation consisted of transferring the numerical data for each heat to a working card and then, using this card, the necessary sums of squares and product sums for a multiple regression analysis were obtained directly from tabulating equipment.

Independent linear regression coefficients were then developed for each variable with the "index of rejects." The linear relations were then checked for curvilinearity with those having a significant relation being presented as shown in Fig. 9A and 9B. While these graphs are captioned in steel plant terminology and it is not the purpose of this article to explain these terms, it is evident that some very definite conclusions are possible with respect to the relation of various factors to the occurrence of rejects in semi-finished steel. From this type of evaluation it is possible to select control levels for a great many quality related factors and attention can then be centered on the control of these variables knowing that such control will help in keeping rejects down to a minimum.

Conclusion

In concluding, it is pointed out that there are many more aspects of the complete quality control procedure than have been covered in this brief report. While some of these are not set up on a statistical basis, in most cases they lend them-

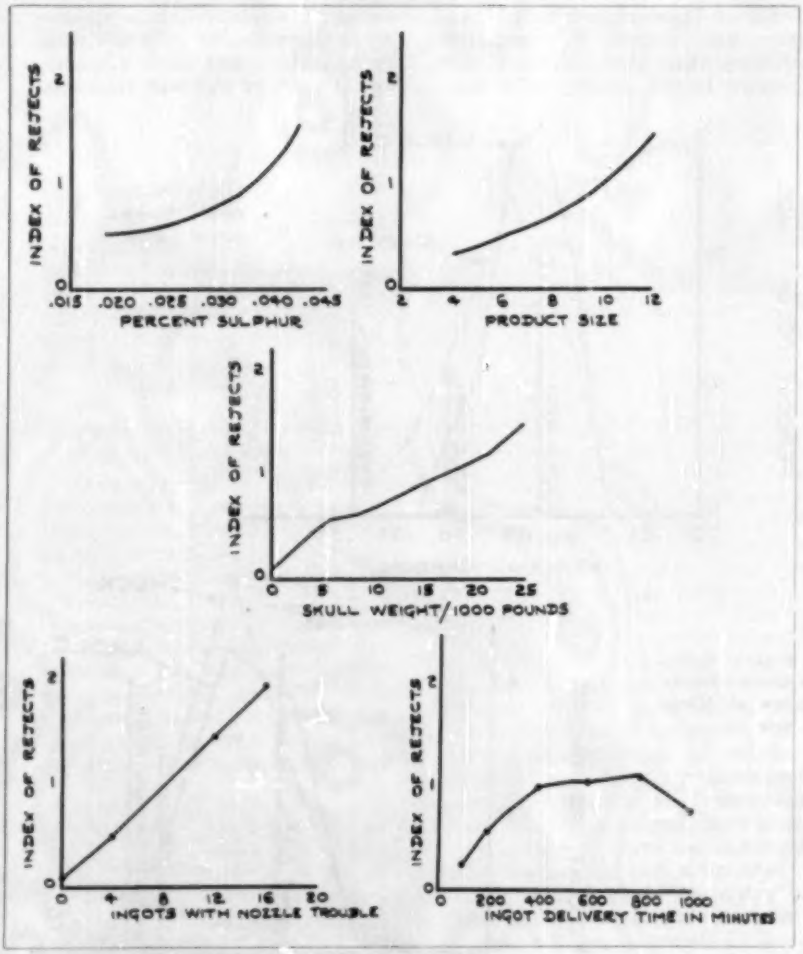
INDEX OF REJECTS
PERCENT SULPHUR
.015 .020 .025 .030 .040 .045
PRODUCT SIZE
2 4 6 8 10 12
SKULL WEIGHT/1000 POUNDS
0 5 10 15 20 25
INGOTS WITH NOZZLE TROUBLE
0 4 8 12 16 20
INGOT DELIVERY TIME IN MINUTES
200 400 600 800 1000

Figure 9A—Relation of Steel Making Factors to Inspection Rejects on Semi-Finished Product

selves to statistical analysis when it is necessary to determine the causes for significant departures from normal processing practice. In addition, the functions of the statistical quality control group include the application of various other techniques in determining the significance of changes in practices which develop from the introduction of new equipment, different raw materials, and improved methods. Some of these other methods can be classified as probability anlysis, moving averages, trend analysis, and significance tests. Lorain Works of National Tube Division of United States Steel Corporation has been a pioneer in the introduction and application of the science of statistical analysis to the many problems which are associated with quality control in the steel industry as indicated by the appended list of references of published material.

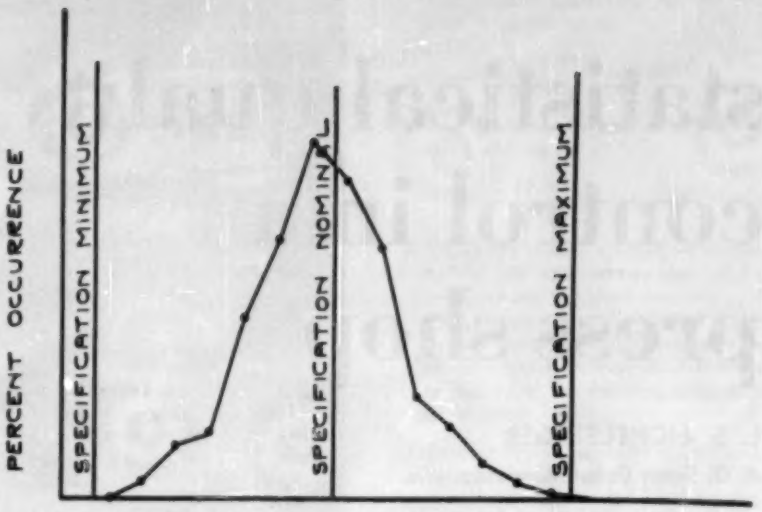

Figure 8—Product Dimension Frequency Distribution of Finished Product Dimension

It may be concluded from present usage and development that the use of statistical methods in connection with quality control procedures is generally accepted by basic industry. The employment of these methods in this type of industry has a much wider range of application in the field of process control and investigation however, than in the otherwise accepted areas of sample inspection which have proved to be suited to the lighter fabricating industries.

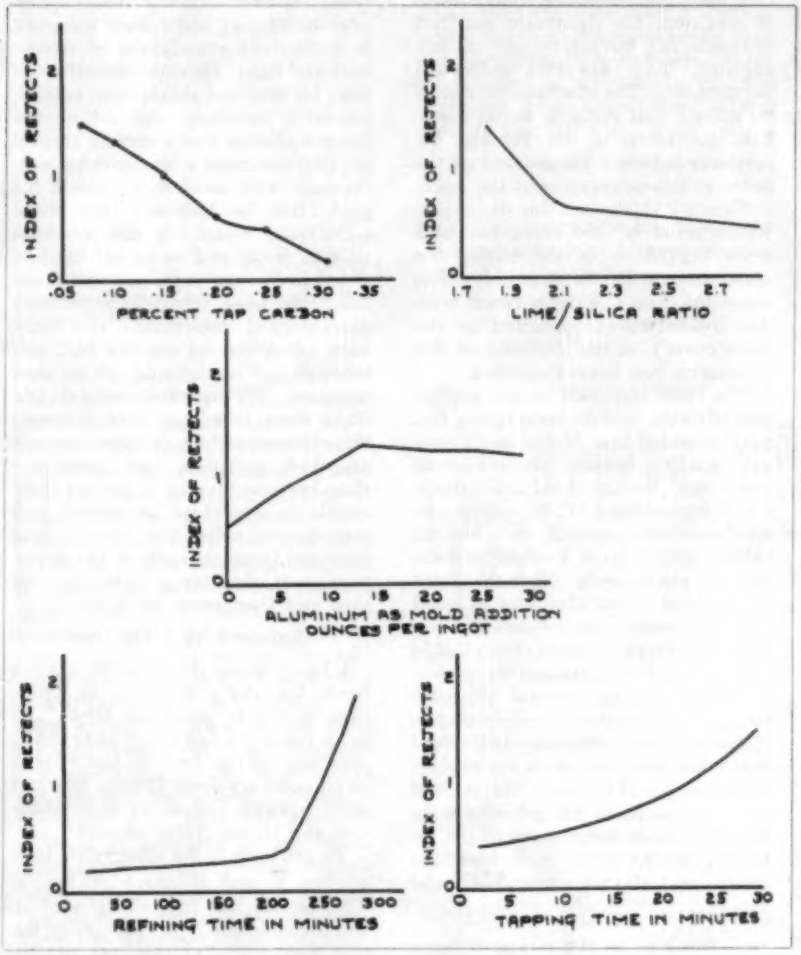

Figure 9B—Relation of Steel Making Factors to Inspection Rejects on Semi-Finished Product

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statistical quality control in a press shop*

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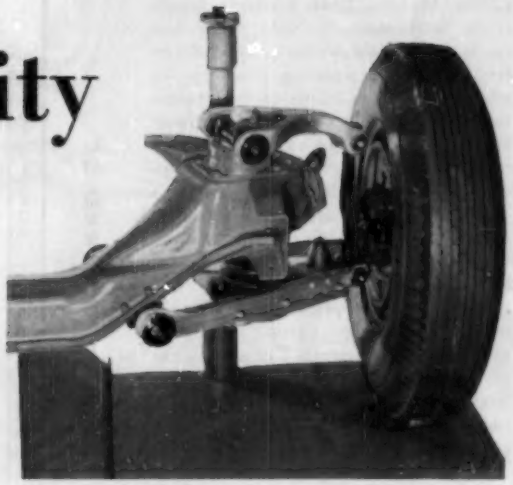

Figure 1—Control Arm Assembly

Introduction

A control arm is essentially an assembly of four stampings. It is a more complex collection of stampings than one usually sees and there are some dimensions that call for more precision than is usually the case. The upper and lower control arms when assembled in an automobile provide the front wheel suspension and are therefore a most important functional part of a car. Riding comfort, efficiency of steering, and safety all depend upon it. Figure 1 shows the control arm assembly on the frame. We will discuss an SQC application on the right and left arms of the lower control arm.

Figure 2 is a diagrammatic view of some of the manufacturing operations that go into the lower control arm assembly.

Notice that all parts start with a blank, which receives one or more forming operations and some piercing and then these parts are put together. There are some further operations on the assembly such as reaming and threading the holes in the ends of the arms. These holes must be in line because they take a shaft in the customer's assembly and if the holes are not in line and the thread lead is off, the customer has assembly trouble and assembly trouble on an automobile line is a very serious matter.

In a sense the control arm itself is incidental to this discussion. What we are going to consider is an application of statistical quality control to one characteristic in the processing of the two arms of the lower suspension. Notice that the lower suspension is not a symmetrical assembly. The two component arms are not equidistant from the center line of the assembly. Moreover, throughout their lengths they do not maintain the same distances from center. In addition, the right arm and left arm are not mirror images of one another. They are two individual components. The characteristic with which we will concern ourselves in this discussion is the vertical dimension between the centers of the holes in the extremities of the arms.

Figure 3 illustrates this dimension which must be the same for both arms regardless of the angles the arms assume in the assembly. The inspector has a fixture fitted with dial indicators (as depicted on the front cover), so the checking of this dimension has been simplified.

The chief inspector of the control arm division that manufacturers this part attended one of the basic ten-day quality control courses some years ago. He has spent most, if not all, of his working life in a shop, has an excellent natural mechanical ability, plus a good working knowledge of engineering. Now these are all the traits you also find in good old fashioned, hard-headed shop men who know shop practices inside and out and who frequently give a statistical quality control program such a rough time in its early stages. However, this particular individual saw what SQC meant to accomplish in the shop and he knew that he had some problems in his job where he thought these techniques might be useful. So he came back from the course and started using SQC, and kept on using it, and he will always use it because of the many benefits he has derived from it. The rewards from SQC did not happen over night, nor were they achieved in a constant atmosphere of sweetness and light. He experienced more than his share of skepticism, apathy, passivity, derision, and all of the other obstacles that a quality control practitioner must often fight his way through and around to reach his goal. But he believed that these techniques would do the job that needed doing and so he set his jaw about five or six years ago and there has never been, in my experience, a more dogged, determined, and stubborn adherence to see the SQC job through as was displayed in that division. His quality control life these days is much more pleasant than it used to be since his methods are now accepted throughout the shop because they have proved their worth to operating personnel and management alike. But it took a long time and large amounts of perseverance, tact, diplomacy, patience, and now and then some coddling.

Approach to a Problem

I have taken the time to digress from the main problem in order first, to try to point out that there is no royal road to a successful SQC program, and second, to pay tribute to an ordinary John Citizen who did a remarkable job under some difficult and trying circumstances.

To get back to the discussion, look at the $\bar{X}$ and R chart in Fig. 4. This is not the first chart used in the division nor is it necessarily the one that produced the best results. It just happens to be one which led into some interesting situations. No-

*Presented June 16, 1954 at a short course on "Introduction to Quality Control by Statistical Methods," College of Business Administration, Marquette University, Milwaukee, Wis.

Figure 2—Control Arm Manufacturing Operations

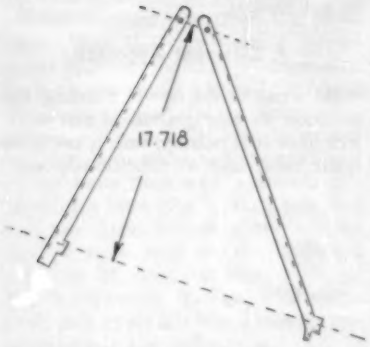

Figure 3—Common Dimension Between Hole Centers in Both Arms

tice in the first place that we are apparently plotting more than one dimension on the same chart. Plotting more than one dimension on an $\bar{X}$ and R chart is not usually good practice and is to be discouraged because it leads more often to confusion than anything else. But there are exceptions to every rule and this is one of the exceptions that paid off. In the shop, they use red and blue pencils which helps reduce the confusion that otherwise results. Actually the double sets of data refer to the same dimension because the centers (Fig. 3) must be the same for both component arms. The solid line shows the performance of the left arm and the dashed line that of the right arm. Note the alternate columns of data and the method of alternate plottings. In other respects this is a conventional $\bar{X}$ and R chart. The control limits were extended from the chart immediately preceding this one on the same operation. There were many previous charts on this particular operation, some of which showed a more unstable condition than this one does, but all of which support the conclusions that can be drawn from this one. From the control charts and other information plus experience, it was obvious that:

- The dimension was often out of the drawing tolerances
- Pooling the ranges for both arms, we can estimate a process capability of

$$\pm \frac{3\ (0.00396)}{2.326} = 0.0051$$

The process capability for the left arm is estimated as

$$\pm \frac{3\ (0.0049)}{2.326} = 0.0063$$

and the process capability for the right arm as

$$\pm \frac{3\ (0.0030)}{2.326} = 0.0039$$

- Using the widest spread, as shown by the left arm, it was decided to consider the inherent capability of the process to be ± 0.006. This is to say that the natural tolerance of the process was ± 0.006 as compared to the drawing tolerance of ± 0.005
- Insofar as averages are concerned, both arms seemed to come off the operation at the same level for the most part.

All the difficulty with this dimension lay in the erratic averages. The inspection department felt that the natural tolerance of ± 0.006 would be acceptable provided the operation was kept "in control" around the nominal dimension (0 on the chart.) This looked like a straight forward approach, so now to present these simple and undeniable facts to operating personnel and let them decide how they could best achieve this obviously desirable situation. The facts were duly presented and the story told, but nothing happened. The conversation went a little like this:

Quality Control: The chart shows you can hold ± 0.006 and we are

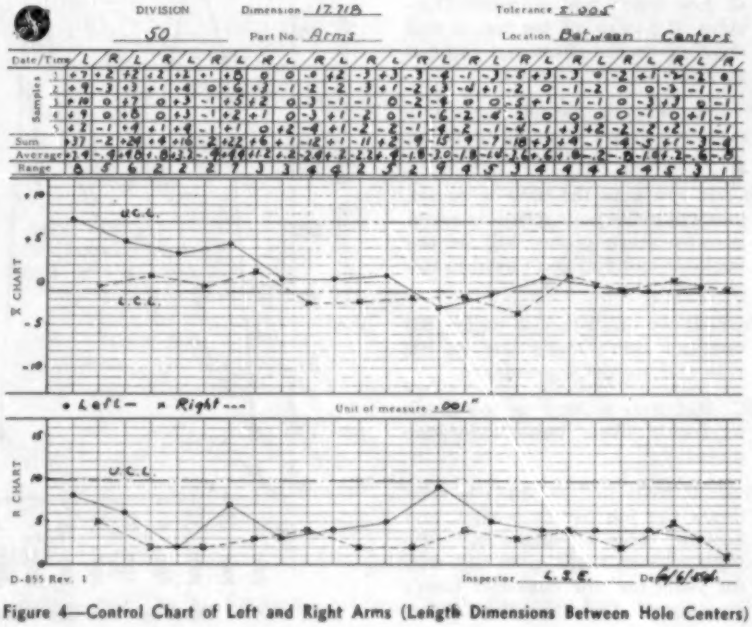

Figure 4—Control Chart of Left and Right Arms (Length Dimensions Between Hole Centers)

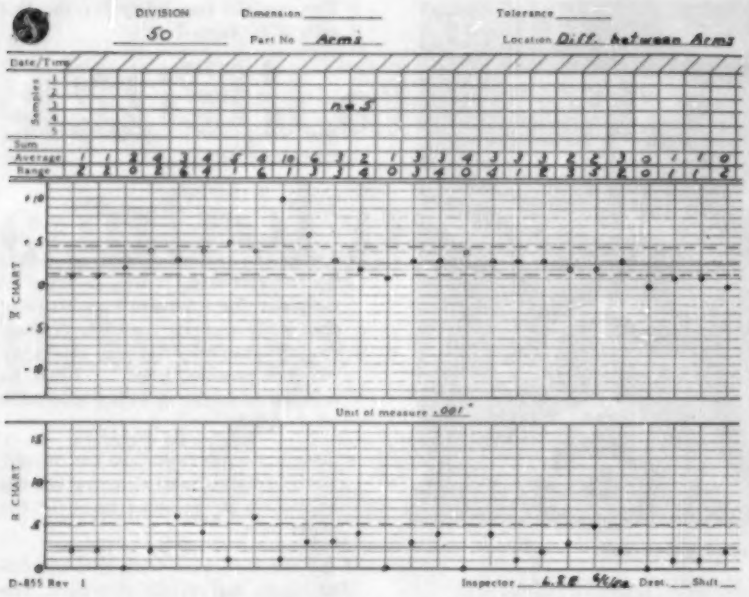

Figure 5—Differences Between Paired Arms

willing to settle for that even though the drawing says ± 0.005. All you have to do is set up the operation at the nominal dimension and you are in business.

Production: On the chart it looks good but we can't do it in the shop.

QC: Why can't you do it?

Prod: Our setup man doesn't have enough time to locate right at the nominal dimension.

QC: Well, it doesn't have to be set at exactly nominal. A little bit high or low won't matter much. Besides, if you're off too far, it will show up on the chart and you can stop the job and re-set it.

Prod: Look, once that job starts running, we aren't stopping to re-set it. We got a schedule to make.

QC: If you take the time to re-set, you will make your schedule easier because more pieces will be acceptable and you don't need to run so many.

Prod: If we don't run so many, the operator don't make out on his rate and we get a grievance.

QC: But it is costing us too much to repair these out-of-tolerance pieces.

Prod: It costs just as much to shut down the job for re-setting, and besides, why all the fuss? We been making these arms this way for years and the customer hasn't ever complained about them.

This last was a clincher and the chief inspector knew it because the customer had been receiving out-of-tolerance arms and had been putting them into automobiles with no apparent ill effects. So why bother about it at this late date? Nobody but the quality control man was convinced that any corrective action was worthwhile, so nothing was done.

But, although the customer had no reason for complaint about this particular dimension, it did create a problem in our own shop on a subsequent operation after the component arms were assembled. When the pierced holes were not reasonably well in line, the reaming and threading operations were in trouble and too many stoppages were occurring and too many pieces were being scrapped or repaired or both. Maybe the customer wasn't complaining but our assembly lines were and so were the cost accountants. Something had to be done. But the chief inspector had charted the operation, had come up with a straight forward diagnosis of the problem, and yet it had failed to get results.

A Different Approach

So what to do now? Finding the solution to any puzzle is not easy, but once it is pointed out, it becomes quite clear and so ridiculously sim-

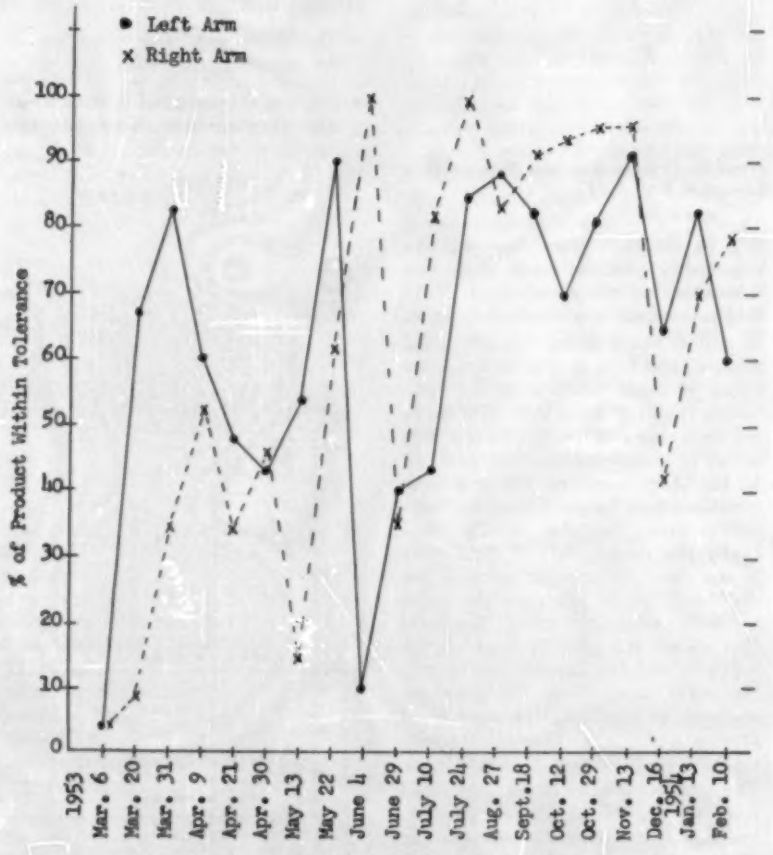

Figure 6—Percentage of Arms Within Drawing Tolerances

ple, that the wonder is why it took so long to get around to it. The control chart was the key that unlocked the door to the solution in this case, but a lot of shop experience and know-how also went into it. A good knowledge of the product and its end use, plus some applied psychology also went into the solution.

From his experience the inspector was aware that there was no trouble in the subsequent operations on the assembled part if the two component arms were of the same dimension. Whether the dimension was in or out of tolerances made little or no difference if both arms were alike. Moreover, everyone else concerned with the job was aware of this same fact, but it was one of those things that everyone knew about: it existed, but so did the weather, and you took both as they came.

At this point the inspector went back over some of his charts and plotted another one from the same data. This time he plotted differences between the center dimensions on the right and left arms. He found these differences to be quite consistent, as was reasonable to expect because both arms are stamped out at the same time with a double die. Each arm falls into its own tote box and the inspector picks one off the top of each box so the adjacent columns of data on the chart of Fig. 4 represent five pairs of arms, each pair of which was made at approximately the same time.

The chart plotted from the differences of these successive readings looked good enough to the inspector to follow up, so he went to the foreman in charge of the operation with a proposition. He told the foreman that he was going to stop trying to hold the job to the drawing dimension, but that he wanted to collect some data from the job for another idea he had. So would the foreman just go ahead and make the arms without worrying about the center dimensions. The foreman was willing to run without the interference of an inspector for the rest of his life if need be and said so. The pieces were accordingly charted and Fig. 5 is the result.

As evidence of a well controlled process, this chart leaves something to be desired, but remember that it represents only a collection of data and that there was no attempt made to control the operation. Nevertheless the ranges look good enough to conclude that right and left arms could be controlled between differences of zero to 0.006 and around an average of about 0.003? Subsequent data would undoubtedly alter these estimates but it was felt that when the operation was controlled, the new estimates would be for the better. Furthermore, a difference of 0.006 or less was acceptable insofar as subsequent operations were concerned, so the time seemed ripe to discuss quality control with operating personnel once more.

Remember that the first attempt at achieving a controlled situation was based on drawing tolerances that were not too realistic from the standpoint of the final assembly and functioning, and therefore the presentation fell on deaf and unwilling ears. The second presentation was based on a "practical" condition of which everyone was aware and could easily understand. Armed with the same kind of a chart and an argument similar to the first one, the inspector made his point and this time received immediate agreement and a real willingness to cooperate from the production personnel. Thereafter an $\bar{X}$ and R chart on differences between paired dimensions was used and the troubles on subsequent operations began to disappear as the arms became more and more uniform in length. At the same time, and as a by-product of the main objective, the proportion of arms that fell within drawing tolerances took a decided upturn. Remember that the prevailing attitude in this respect had been one not only of why bother to hold the tolerances since they didn't mean anything anyway, but also that it was impossible to do a better job. Now with the control emphasis on uniform lengths rather than on maintaining a drawing tolerance, the proportion within tolerances improved anyway. Figure 6 graphs this improvement which began about July or August, 1953 when the new chart began to take hold.

Credit for this performance cannot be taken solely by the control chart. After all, there was nothing wrong with the first control chart application on this job. The SQC was there but nothing happened. When the second application caught on, the situation improved very quickly because the persons who could do something about it were convinced

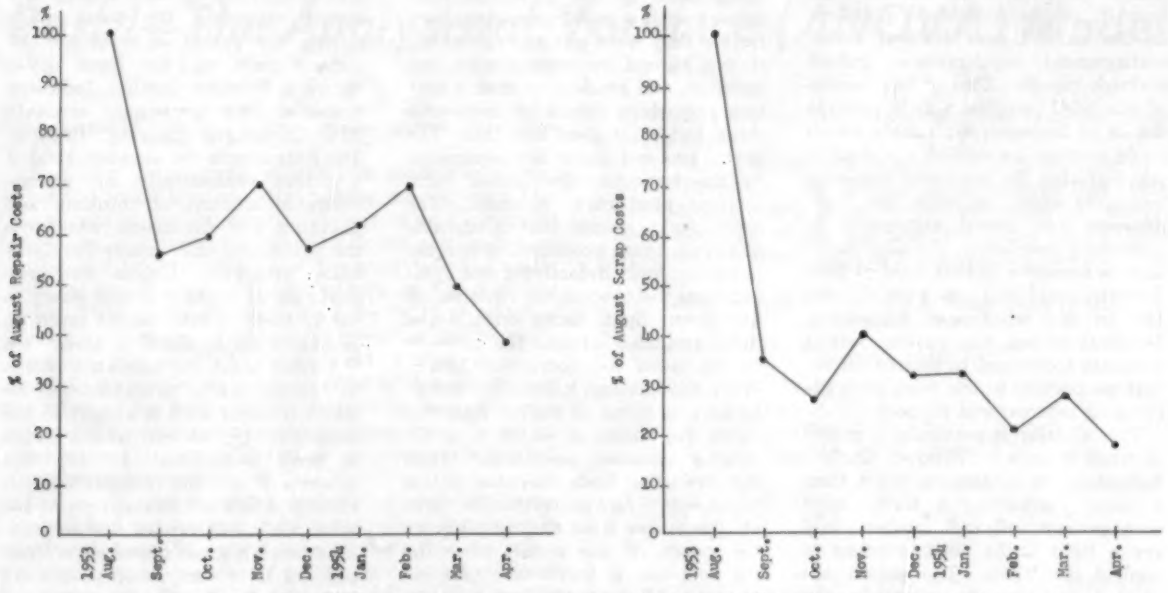

Figure 7—Left: Trend of Repair Costs for Component Arms. Right: Trend of Scrap Costs for Component Arms

that they could make those arms alike without any trouble at all. In the first case they felt that drawing tolerances could not be held under any circumstances, but in the second case they knew that if they were not forced to hold the tolerances, they could make arms that would assemble and function properly. Because they were willing to make the second case work, they achieved the first objective as a by-product.

Bear in mind that the first control chart demonstrated that tolerances could be held for the most part. There was nothing wrong with the charts. The difficulty was in the approach used to convince someone that he could do something which he was sure he couldn't do. I do not mean that the approach used was in error because it was not. It was the most logical one to use and had no real reason for failing.

The lesson here is that control charts alone cannot do the job. You must obtain in one way or another the active and willing participation of those who make the product. Also this case history illustrates that old and time worn adage "If you do not at first succeed, try, try, again." There is much disillusionment on the SQC road, but the gold is there if we have the perseverance and ingenuity to get it out.

Other Quality Control Activities

Sooner or later a successful SQC program must have the active support of management. A quality control man can accomplish a number of things without such support, but his progress comes to a loose end unless he does attain it. How he gets it, is his individual problem. In the control arm division active management support was gained through results. One of the results of this SQC program was to provide the chief inspector with facts which could neither be denied nor evaded successfully. So the chief inspector began to come up with the right answers and sound arguments in increasing frequency. An alert manager is sensitive to that kind of performance and this manager did not fail to see what was happening. Needless to say, the quality control program continued to flourish in direct proportion to the manager's increasing interest and support.

This division is particularly proud of what it calls a "Product Quality Indicator." It is nothing more than a panel containing a traffic light arrangement of red, amber, and green light bulbs with switches to control the lights. The panels are located at strategic points in the production lines where they can be easily seen by the personnel concerned with a particular operation. Before they were put into operation, it was agreed by management, inspection, and production that a certain procedure would be used with these lights. It goes like this: The green and red lights are controlled by the inspector; the amber light, by the production foreman. The green light means that acceptable quality is being produced. When the inspector finds defective parts coming from the process, he switches off the green light, turns on the red light, and also advises the foreman of the need for corrective action. When the foreman has made the correction, he turns off the red light and lights the amber at which time the process resumes operation. When the inspector finds that the action taken was in fact corrective, he turns off the amber light and switches on the green. If the action taken by the foreman is ineffective, the inspector will turn the red light on again and repeat the routine. He will also, of course, take appropriate action regarding the parts made during the period of trouble. The picture used on the front cover shows a Product Quality Indicator and also two component arms in their respective gaging fixtures. The Indicator is the simplest kind of a gadget mechanically, but a considerable amount of thinking and planning and discussion went into the procedure that makes the Indicator effective. Unless everyone could agree on how it was going to work, there would be no point in setting it up in the first place. On the other hand, the necessary action to correct faulty processes can be taken without such a gadget so the gadget is only an instrument which in itself is nothing. In this case however it was the focus or nucleus around which all factions could resolve their differences and as such it assumed a great importance. Control charts to many shop people are just so much gibberish. Colored

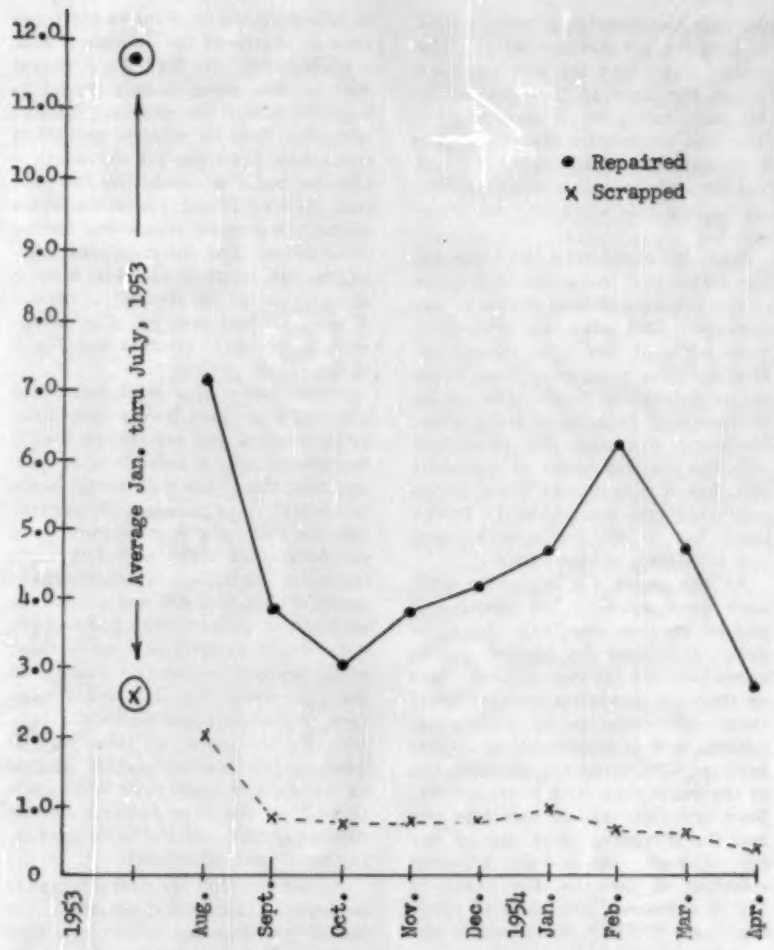

Figure 8—Percentage of Component Arms Defective

lights are understandable and appealing. The fact that the inspector turns them on and off only after consulting his control chart is, to the operator, of small importance. The red light carried an authority that an out of control point seldom reached.

We have discussed only a very small part of the entire SQC activity in this division. What has been done on the component arms has been done again and again on most of the many stampings and parts manufactured. In addition, the receiving inspector checks incoming materials to definite acceptable quality levels and according to published sampling plans. Vendors receive copies of inspection reports and so do the production control and purchasing departments. Rejected material when not returned to the vendor is handled in the division at the vendor's expense. At the other end of the process, the end product is again inspected to a defined acceptable quality and the sampling plan used is based on the continuous sampling techniques developed by Harold Dodge of Bell Telephone Laboratories, Inc.

Some Cost Pictures

We cannot leave this discussion without a peek at the monetary side of the picture. Figure 7 shows the reduction in repair and scrap costs since August, 1953 to April, 1954, for the componet arms about which we have been talking.

Notice the sharp improvement in September and the continuing trend downward in both cases. That this is due in part to a decrease in the amount of defective material made, is shown in Fig. 8 of the percentage defective over the same period.

Prior to August, 1953 when this control activity began to make itself felt, it was considered an excellent performance if the repair percentage got down to 11½ percent and the scrap got down to 2½ percent. This condition is exemplified by the points in Fig. 8 for the first seven months of 1953. The improvement is obvious.

Conclusion

The men responsible for the SQC program in the control arm division are no different than men in other factories insofar as an understanding of the subject goes. What they have done has been done elsewhere before and is being done more and more frequently day by day. An expert is defined by "Boss" Kettering as a man who knows all the reasons why something cannot be done and many such experts cross the paths of the quality control man. Somewhere someone has reaped the rewards of SQC in your field, others have used SQC to solve problems as knotty and as peculiar as yours are, and still other quality control men have been faced with and overcome the same kind of personalities as you will meet. Believe it or not—your problem is not new and different, and your field has no more variables in it than there are in the other fellow's field. You will never have an SQC program of any kind unless you start somewhere.

The success of SQC does not depend upon whether you or you or you like it or practice it, but the personal success of you or you or you will be greatly enhanced by a knowledge and practice of statistical quality control.

Fundamentals of Analysis of Variance

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Part I—The Analysis of Variance (ANOVA) Model

Ed. Note: This is the first in a series of three articles on the fundamentals of analysis of variance written by Prof. Hicks. Parts II and III will appear in subsequent issues.

Basically the analysis of variance technique is just what the name implies—partitioning the variance (i.e. the square of the standard deviation) of an experiment into parts in order to test whether or not certain factors introduced into the design of the experiment actually produce significantly different results in the variable tested. That is, for example, does the mold in which a casting was made affect the porosity of the casting? Does the scale used affect the weight of a vial of medicine? In each case, we are interested in testing whether the effect of the factor on the variable measured is significant when compared with the random variation in the process. Hence the F test or variance ratio is used to make such comparisons.

Let us consider a specific example adapted from some unpublished data collected at Purdue. Here the variable measured (say X) is the rate of fluid flow in cubic centimeters and we are interested only in the effect of one factor, nozzle type, on this rate of flow. The results in Table I are for five runs through each of the three nozzle types.

The factor, nozzle type, is said to be in three categories as we have just three nozzles. It is assumed that these are the only nozzle types we are interested in. We do not wish to generalize our results to other nozzle types of which the three might be but a random sample. This

TABLE I—Number of c.c. of Fuel through three Nozzles for Five Trials.

		NOZZLE TYPE		
		A	B	C
Trial Number	1	96.6	96.6	97.0
	2	97.2	96.4	96.0
	3	96.4	97.0	95.0
	4	97.4	96.2	95.8
	5	97.8	96.8	97.0

is an important point: we are considering only these three nozzle types, so we have a factor in fixed categories. Had we been interested in these three nozzle types as a random sample of a whole population of nozzle types, nozzle types would be a random effect. In a one-way classification (one factor) like this one, the analysis used to get the results would be the same for either a random or a fixed effect, but the significance tests performed would be interpreted differently. This discussion will be confined to designs with fixed factors only.

For the one-way classification above, consider any observation—call it X_{ij}, where i is the number of the observation and j the category of the factor designation, i.e. the column in which X_{ij} is located. Thus $X_{23} = 96.0$ is the second observation for the third nozzle type. Now this number is affected by the category (or column) it is in, and also by some random error. We might then set up the model:

$$X_{ij} = \bar{X}' + B'_j + Z'_{ij}$$

where $\bar{X}'$ is a common term in all populations from which the experimental data were drawn, B'_j is a term designating the category or bias of the j factor from which the observation came (j = 1, 2, 3, in our problem) and Z'_{ij} is a random error. Our problem is to test the hypothesis that all three of these categories (or columns) came from like populations, or that: $B'_1 = B'_2 = B'_3 = 0$. If the least squares technique is applied to this model above, we find, for a sample of N observations:

$$X_{ij} = \bar{\bar{X}} + (\bar{X}_j - \bar{\bar{X}}) + (X_{ij} - \bar{X}_j)$$

where: $\bar{\bar{X}}$ is the best estimate of the population mean $\bar{X}'$.

$\bar{X}_j - \bar{\bar{X}}$ is the best estimate of the population B'_j.

and $X_{ij} - \bar{X}_j$ is the best estimate of the error or residual.

We note that this expression is a mathematical identity as both sides of the equation are equal for all values of X_{ij}.

Transposing in this identity:

$$(X_{ij} - \bar{\bar{X}}) = (\bar{X}_j - \bar{\bar{X}}) + (X_{ij} - \bar{X}_j)$$

which says that the deviation of each observation (X_{ij}) from the grand mean of all observations in the experiment ($\bar{\bar{X}}$) can be broken down into two parts: the deviation of the category mean from the grand mean plus the deviation of an observation from its own category mean.

Squaring both sides of this identity and summing first over all observations within a category and then over all k categories, the resulting expression is:

$$\sum_j \sum_i (X_{ij} - \bar{\bar{X}})^2 = \sum_j \sum_i (\bar{X}_j - \bar{\bar{X}})^2 + 2 \sum_j \sum_i (\bar{X}_j - \bar{\bar{X}})(X_{ij} - \bar{X}_j) + \sum_j \sum_i (X_{ij} - \bar{X}_j)^2$$

or,

$$\sum_j \sum_i (X_{ij} - \bar{\bar{X}})^2 = \sum_j \sum_i (\bar{X}_j - \bar{\bar{X}})^2 + \sum_j \sum_i (X_{ij} - \bar{X}_j)^2$$

The middle term on the right hand side has vanished in the second expression since the summation of the cross product term equals zero. This expression says that the total sum of squares (of deviations) equals the sum of squares among category means plus the sum of squares within the categories. When each of these sums of squares (S.S.) is divided by the proper number of degrees of freedom (d. f.), the quotient represents an unbiased estimate of the population variance from which the data came. If our hypothesis is true that the nozzle types do not affect the mean rate of flow, then either the sums of squares among categories or the sums of squares within categories could be used to estimate the population variance, and each estimate is of the same variance, and the ratio of the two estimates will follow an F distribution. Hence an F test using the proper number of degrees of freedom will test the hypothesis that the means of all three categories are from the same population, or that $B'_j = 0$ for all j.

Now the actual calculations are not made by subtracting and getting the square of all these deviations but by making use of the binominal expansion of $\sum_i \sum_j (X_{ij} - \bar{\bar{X}})^2$. We can set up three rules for analyzing the effect of any factor on a given variable:

1) Square all the observations in the experiment and add, then subtract from this the square of the sum of all observations divided by N. This we call the total sum of squares. The sum of all observations squared and divided by N is often referred to as a correction term. Associated with the total S.S. are N−1 degrees of freedom.

   Symbolically this rule is: $\sum_i \sum_j X^2_{ij} - T^2/N$,

   where T = grand total for the entire table.

2) Sum all observations for each category of a given factor, square this total and divide by the number of observations for this category, sum for all categories, then subtract the correction term as in (1). This is called the S.S. for the given factor and has k−1 degrees of freedom associated with it, where k is the number of categories given.

   Symbolically this rule is: $\sum_j \left[\frac{(T_j)^2}{n_j}\right] - \frac{T^2}{N}$

   where T_j is the total of all n_j observations in category j.

3) Subtract the S.S. for the factor (or factors) from the total S.S. This is the residual or error S.S. The degrees of freedom are (N−1) − (k−1) = N−k for the design with just one factor.

The data are then summarized in a table. Let us try this on our rate of flow problem. It will simplify the calculations considerably if the data are first coded. This can be done by subtracting 96.0 from each observation and then mulitplying each observation by 10. The results are all integers as shown in Table II.

Applying the rules, the total S.S. is 675.73. For the effect of the three nozzle types, applying step (2) we add all readings for each nozzle type, square, divide by five, and add for all three nozzles minus the correction term, giving 211.73. (Actually, here we divide by five after summing over all three types as the numbers of observations for each category are equal.) The remainder is 675.73 − 211.73 = 464.00. This is the error

S.S. which is used as our "yardstick" to test the significance of the different nozzle types on the data, i.e. to test the hypothesis that $B'_1 = B'_2 = B'_3 = 0$.

The data are summarized at the bottom of Table II. The mean square is the unbiased estimate of the population variance found by dividing each S.S. by the associated number of degrees of freedom, and F is the ratio of the among nozzles mean square to the error mean square. In this problem F = 2.74. Consulting an F table with 2 and 12 d.f. the F necessary to claim a significant difference between nozzle types at the 5 percent level of significance is $F_{0.05} = 3.89$. Since our F is less than this, we conclude that our hypothesis cannot be rejected, and we behave as though the three nozzle types produce no differences in the mean rate of flow.

Now some bright boy in the organization notes that five different operators worked these three nozzles and the data could be analyzed further for possible differences in rate of flow due to the different operators. The problem now becomes an analysis of variance with a two-way classification of the data; i.e., two factors: nozzle type and operator, one in three categories (three nozzle types) and the other in five categories (five operators). Again we are assuming that the five operators are the only operators we are interested in, i.e. operators are a fixed factor. As each operator has worked with each nozzle type, we can analyze the data for differences in rate of flow among operators as well as among nozzle types. The model we assume now is:

$$X_{ij} = \overline{X}' + B'_j + C'_i + Z'_{ij}$$

where C'_i has been introduced to account for possible differences among operators where i = 1, 2, 3, 4, and 5. The analysis proceeds as before except for analyzing the five categories of the operator factor. In Table III, we have the analysis and the summary.

Here we applied the same rule (No. 2 above) to each operator—add for each operator, square, divide by three, and sum for all five operators minus the correction term.

$$\text{Symbolically: } \sum_i \left[\frac{(T_i)^2}{k}\right] - \frac{T^2}{N}$$

This source of variation or S.S. among operators is also subtracted from the total S.S. leaving a different and "purer" error term than before. If we now recalculate the mean squares (that between nozzles stays the same), we can compare the among nozzles mean square with our revised estimate of the error mean square and also can compare the operator mean square with this error mean square. The F values are now as given in Table 3 along with their five percent significance F values. The results show that neither the nozzles nor the operators produce a significant difference in the average rates of flow even though we have now reduced the error term by accounting for another possible source of variation. In the first analysis (one-way classification), the operator effects were included in (that is, "confounded") with the error term. In actual practice, this other source of variation should have been foreseen in the original design and the second model used as shown in Table III. We thus fail to reject the hypothesis that: $B'_1 = B'_2 = B'_3 = 0$, and also fail to reject the hypothesis that $C'_1 = C'_2 = C'_3 = C'_4 = C'_5 = 0$.

TABLE II—Coded Data from Table I

		A	B	C	
Trial Number	1	6	6	10	
	2	12	4	0	
	3	4	10	−10	
	4	14	2	− 2	
	5	18	8	10	
Sums:		54	30	8	92
Sums of Squares		716	220	304	1240

$$\text{Total S.S.} = 1240 - \frac{(92)^2}{15} = 675.73$$

$$\text{Nozzle S.S.} = \frac{(54)^2 + (30)^2 + (8)^2}{5} - \frac{(92)^2}{15} = 211.73$$

Source of Variation	S.S.	d.f.	M.S.	F	$F_{.05}$
Total	675.73	14			
Among Nozzles	211.73	2	105.86	2.74	3.89
Error	464.00	12	38.67		

TABLE III—Two-way Classification: Nozzle Types and Operators

		NOZZLE TYPE			
		A	B	C	Sums
Operator Number	1	6	6	10	22
	2	12	4	0	16
	3	4	10	−10	4
	4	14	2	−2	14
	5	18	8	10	36
	Sums	54	30	8	92

$$\text{Operator S.S.} = \frac{(22)^2 + (16)^2 + (4)^2 + (14)^2 + (36)^2}{3} - \frac{(92)^2}{15} = 185.06$$

Source of Variation	S.S.	d.f.	M.S.	F	$F_{.05}$
Total	675.73	14			
Among Nozzles	211.73	2	105.86	3.03	4.46
Among Operators	185.06	4	46.26	1.33	3.84
Error	278.94	8	34.87		

A further extension of our analysis would be possible if we were to repeat the same experiment, thus getting at least two observations for each operator-nozzle combination. This we call a replication and it is assumed that both (or all) replications are taken under the same conditions. Replication will enable us to analyze for a possible interaction between the two main factors, i.e. between nozzle types and operators. The replication would yield a still better estimate of the error in the experiment than was possible before. Of course this also requires more data. The model would now be:

$$X_{ij} = \overline{X}' + B'_j + C'_i + D'_{ij} + Z'_{ij}$$

where D'_{ij} represents the possible interaction between certain categories of one factor with categories of the other factor. Repeating the above experiment three times the results (coded) might be summarized as in Table IV.

TABLE IV: Nozzles vs. Operators Data with Replication

Operator															
1			2			3			4			5			
Nozzle			Nozzle			Nozzle			Nozzle			Nozzle			
A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	
6	13	10	26	4	−55	11	17	11	21	−5	12	25	15	− 4	
6	6	10	12	4	0	4	10	−10	14	2	− 2	18	8	10	
−15	13	−11	5	11	−14	4	17	−17	7	−5	−16	25	1	24	

Notice that this table has been set up somewhat differently than the usual 3 by 5 table as Table III. It is hoped that this will give a clearer idea of what interaction is and how its S.S. is computed. If we forget about nozzle types and operators for the moment and analyze the above as a one-way classification of 15 cells we find, applying the same rules set down earlier that:

$$\text{The total S.S.} = 7085.24$$
$$\text{Among cells S.S.} = 4047.24$$
$$\text{Within cells S.S.} = 3038.00$$

Now, the among-cells variation includes variation among operators and among nozzle types as well as chance variation. If we consider the S.S. for each of these main effects, we first calculate the operator S.S. by summing over the nine readings for each of the five operators (e.g. the total of the 1st three columns in Table IV gives this sum for operator 1 etc.) We find:

$$\text{Operator S.S.} = \frac{(38)^2+(13)^2+(47)^2+(28)^2+(122)^2}{9} - \frac{(248)^2}{45} = 798.79$$

For nozzle types, we sum over the 15 readings for each of the three nozzle types (e.g. the sum for nozzle type A is the total of columns 1, 4, 7, 10 and 13 in Table IV) and find:

$$\text{Nozzle S.S.} = \frac{(169)^2+(111)^2+(-32)^2}{15} - \frac{(248)^2}{45} = 1426.97$$

When these two main effect S.S. are subtracted from the among-cells S.S., we find that there is some variation left over (1821.48), which is unaccounted for by the nozzle types or by the operators. This is what we label the nozzle-operator interaction or N×O interaction S.S. This is a first order interaction as it is the simplest type observable in any experiment. It represents variation between the means of these "cells" not attributable to either of the main effects and is present because of the way certain operators might interact with certain nozzle types. For example, the second operator might run nozzle type A consistently too fast while running type C consistently too slowly and this would not show up as a nozzle or operator effect if another operator tended to reverse this by running nozzle C too fast and A too slowly. We now summarize for Table IV.

TABLE V: Summary of Nozzle, Operator Data with Replication

Source of Variation	Sum of Squares		d. f.	Mean Square	F	$F_{.05}$
Total		7085.24	44			
Among cells	Among Nozzles 1426.97		2	713.49	7.05	3.32
	Among Operators 798.79	4047.24	4	199.70	1.97	2.69
	N×O Interaction 1821.48		8	227.68	2.25	2.27
Within cells (error)		3038.00	30	101.27		

Referring to Table IV with its 15 cells there are 14 degrees of freedom between these cell means. Now 2 d.f. may be accounted for by the three nozzle type differences, and 4 d.f. by the five operator differences which leaves: 14−2−4 = 8 d.f. for the interaction. In general, the interaction d.f. equals the product of the d.f. of the main effects producing this interaction. Here: (2)(4) = 8.

Whether to pool or not to pool the error and interaction for testing the main factors is still debatable among the experts, but we can test the significance of the interaction mean square with the error mean square as the "yardstick." If this is not significant, we can test the two main factors versus this error term or possibly pool the interaction and error terms as the yardstick for testing these main factors. The results above show the nozzle types producing a highly significant difference in mean rate of flow while operators show no significant differences, nor is the interaction quite significant if we use the five percent significance level.

In this discussion, we have tried to set up some general rules for getting the sums of squares and to review the analysis of variance technique. These general methods can easily be extended to analyze as many factors as you wish to assume in your original model, and also to compute the interaction of the first order or higher. It should be noted, however, that second order interactions are what is left in the among-cells S.S. (among cubes, really) after we subtract out the S.S. for the three main factors *and* all three first order interactions. The designs illustrated here are all factorial designs where each category of one factor is combined with each category of every other factor.

Finally, some mention should be made of the assumptions underlying the analysis of variance technique. The basis assumptions are:

1) The effect of all factors is additive. We have used linear models throughout this discussion.

2) The random errors were sampled from a normal universe.

Often some transformation of the variable can be made if this assumption is not met. How often we see a discrete variable used for analysis such as the number of defective items produced by several machines from several batches of raw material. Such data are likely to be from a binomial distribution, and the normality assumption is only approximately met if the average number of defectives is quite high. However, by using the percent defective as the variable and transforming it by an arc sine transformation, the normality assumption may be better satisfied.

3) The data must exhibit homoscedasticity or homogeneity of variance. That is, we should first show that no significant differences exist among the variances within the cells. This is usually tested with the Bartlett test. When transformations are made to induce normality, we may also expect more homogeneity of variance.

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Local Section News

"... BUT NOT FORGOTTEN"

BALTIMORE The annual dinner meeting was held at the Hotel Stafford on May 16. Dr. Andrew Schultz, head of the department of industrial engineering administration at Cornell University gave a very excellent talk on "Quality control as a management tool." A representative attendance from Baltimore industry enjoyed the occasion.

An outside barbecue followed by an executive committee meeting was held June 27 at the estate of E. R. Harrall, last year's section chairman. Purpose of the meeting was for transfer of files from last year's officers to this year's officers and to lay plans for the 1956-57 program.

BOSTON The third annual seminar sponsored by the section, was held June 18-20. The course, "Quality control for management," was well received this year—some applicants had to be denied because the number of applications exceeded the available facilities. It appears that this unique course is well-established as a continuing activity of the section.

CHICAGO The Chicago section and the Commonwealth Edison Co. of Chicago played host to four notable European educators, namely Messrs. Pierre Ferignac of France, Rolf Dietrighson of Norway, Peter Slors of the Netherlands, and Jean Teghem of Belgium.

These gentlemen were in Chicago under the auspices of the International Co-Operation Administration sponsored by our State Department. They were in Chicago for a seminar on the application of statistical quality control techniques to fabricating processes and clerical problems.

Robert Tenney, section chairman, Eugene Freund, section vice chairman, and Charles Matz, section chairman of the education and training committee, welcomed our visitors to Chicago and the seminar.

On June 28 a dinner meeting of the executive board of the section was held at Younkers Restaurant, at which time the incoming officers officially took office. Mr. Tenney, section chairman, appointed the various committee chairmen for the coming year and the future program was discussed.

CORNING -ELMIRA All committee chairmen for the new year were appointed at the June executive meeting, with attention given by all to broadening the membership base, and increasing attendance at meetings. The section will continue to emphasize a strong educational program, as the various courses given during the past year proved their worth to members at every professional level.

DELAWARE The section was quite well represented at the Montreal convention. Local members who attended included Bill Chelgren, Hillman Harris, Hal Hosford, Joe Meyer, and Ed Niedzielski. All those attending this convention congratulate the convention committee and the Montreal section on the high quality of the papers presented, the sincere hospitality of Montreal and the glorious weather provided. Merci beaucoup.

HARRISBURG The final meeting of the year was a "bull session and problem discussion" period held at the Indian Echo Cave at Hummelstown, Pa. It was an interesting session with much "food for thought" coming from the discussion. Although the attendance was below average, the absentees were excused for a good reason—they were at the convention in Montreal.

The first meeting of the executive committee for the 1956-57 term was held at the Alcoa plant in Lancaster on June 13. Meeting places for the coming year were chosen and the program committee already has a number of prominent speakers lined up for the year.

HUNTSVILLE Election of officers for the coming year and a general discussion of the Montreal convention was held on the evening of June 21 at the Public Library.

KANSAS CITY The final meeting of the '55-'56 season was held June 13 at the Blue Hills Restaurant. Following the dinner and business meeting, which consisted of reports of financial, membership, and general progress for the year, the members heard accounts of the national convention at

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Montreal. Members who attended the convention told of the sessions they attended and of their experiences on the trip. Mike Putthoff, Ivan Davis, and Wm. G. Shepherd participated.

LOS ANGELES The Montreal convention highlights was the theme of the June meeting of the section. Dr. Harry Romig, Summers Gyroscope, Dr. Leo Aroian, Hughes Aircraft Company, and Bill Schwager, Firestone Tire & Rubber Company, gave a very enlightening review of these highlights.

LOUISVILLE Our representation at the Montreal meeting was better than average—ten members from a roster of eighty indicated high interest—especially when we're not exactly living just down the street from Montreal.

The first picnic scheduled by our section was held in June. W. J. Alexander, program chairman, chose a beautiful setting—Reynolds Meadows—the recreation area for Reynolds employees. Though not too many attended, those of us there certainly had a fine time. Boating and admiring fellow members' delightful small fry took close second place to weiners, steaks, and marshmallows.

MILWAUKEE All good things come to an end, only sometimes much too soon. That was the sentiment of the section at the final meeting of the year held at the Miller Brewery. A tour, business meeting, and a wonderful buffet lunch together with the brewery's product made for an enjoyable meeting. Six foreign quality control men who were attending Marquette University's quality control conference were guests.

ST. LOUIS The St. Louis section held their annual social evening of the year combined with the installation of officers at the Forest Park Hotel on May 26. The evening was thoroughly enjoyed by everyone with dancing and dining. Attendance prizes consisting of items donated by various industries were given during the course of the evening.

The executive committee has had one of a series of many meetings it will conduct in formulating plans for the year's activities.

SAN FRANCISCO BAY AREA Dale Lobsinger of United Air Lines was the distinguished visitor and speaker at the May 31 dinner meeting attended by 48 members and guests. His talk, entitled "Quality assurance in supervision," outlined a new and vital application of statistical quality evaluation of supervisory functions and personnel. The presentation was implemented with colored slides and evaluation data.

TOLEDO The June meeting of the section, the last of the 1955-56 season, was held at Devil's Lake, Mich. sponsored by the M & S Manufacturing Co. Although this was strictly a social gathering, the officers for the 1956-57 season were announced.

TORONTO The 1956-57 officers held a meeting June 14 at Collins Radio Company of Canada. Many interesting ideas were put forward for our program starting in September.

UTICA Because of the success of the elementary course in statistical quality control which has become a part of Adult Education Curriculum of the Utica School System, plans are being made for an

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XVI. Mil-Std.-105A.

intermediate and perhaps advanced course to be started in the latter part of September. Several classes in basic statistical quality control will also be held. Fifty-five students successfully completed the basic work so that a high enrollment is anticipated for the intermediate course.

WESTERN MASSACHUSETTS On June 19 our executive meeting was held to finish plans for the 1956-57 season. Maurice Blew, chairman, plans six technical meetings and one social for next season. As to education, an advanced course in the area of operational research is planned for the fall with a basic statistics course for newcomers in the spring. The all day clinic will be on techniques used in "trouble shooting."

Last year this section was able to encourage several people from the life insurance industry to join the society. It is hoped that now the ice is broken, more people can be encouraged to join from this untapped group. Also, with the local SAC air base expanding its activity, this section will search there for new members.

"... CAST THEIR SHADOWS BEFORE"

BOSTON The program for the 1956-57 season is already nearly complete. It is planned to feature several short pre-meeting sessions on the application of selected statistical techniques.

CHICAGO On Sept. 18 at 6:30 pm the Calumet sub-group will hold their first general meeting at Vogels Restaurant, 1250 Indianapolis Blvd., in Hammond, Ind.

On Sept. 18 the newly formed Fox-Valley sub-group will hold its first general meeting at Club Arcada in St. Charles, Ill.

CORNING -ELMIRA A joint meeting with the Ithaca section of the Industrial Engineering Society will be a principal feature of the diversified program planned for members during the fall.

DELAWARE The executive committee is meeting and will continue to meet monthly during the summer to formulate plans for the 1956-57 season. The dates for these meetings will be announced and all members of the committee are urged to attend.

"AS YE SOW . . ."

CHICAGO Beginning Sept. 25 the Fox-Valley sub-group will hold a basic training course in SQC one night a week for 10 weeks. Profs. Paul Randolph and Raymond Swenson of the Illinois Institute of Technology will serve as instructors.

CORNING -ELMIRA Robert Bechhofer, chairman of the education program committee, announces a quality control course aimed at helping production foremen solve their quality problems. The exact starting date will depend on the schedules of the particular personnel involved, but is planned for late September.

RUTGERS UNIVERSITY APPLIED STATISTICS AND SQC CONFERENCE SEPTEMBER 5-12 An advanced conference on applied statistics and statistical quality control will be held at Rutgers University Sept. 5-12. The program is designed to meet the needs of industries by providing their representatives with a practical working knowledge of modern quality control with the emphasis upon the application of techniques useful in isolating and solving important plant problems. The program consists of demonstrations, lectures, and discussions of many actual plant experiences. Registrants will be afforded the opportunity to discuss their own industrial problems with members of the conference staff.

The full-time Rutgers staff members who will be associated with this advanced conference are Professors Allen R. Crawford, Ellis R. Ott, and Mason E. Wescott. An additional feature of the series will be special lectures by Paul S. Olmstead, Bell Telephone Laboratories; Dr. J. Stuart Hunter, American Cyanamid Co.; Enoch B. Ferrell, Bell Telephone Laboratories; and A. B. Mundel, Sonotone Corp.

The fee for the entire series will be $150. This covers reference materials and text. Rooms have been reserved in the Military Park Hotel in Newark, N. J. for those who cannot commute to Newark for class sessions but early hotel reservation is advised.

Application for the series, or additional information should be addressed to: Prof. Allen R. Crawford, Conference Co-ordinator, Rutgers University, University College, New Brunswick, N. J.

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SECOND ANNUAL STATISTICAL ENGINEERING SYMPOSIUM

Above, discussion by the Round Table on Acceptance Sampling at the Chemical Corps Engineering Command Second Annual Statistical Engineering Symposium held recently. Left to right, Moderator Silas Williams, Courtland C. Van Vechten, Robert Banzhaf, Richard Biedenbender, Arthur Stein, Harold F. Dodge, Seymour Lorber, Franklin E. Satterthwaite, Gerald Lieberman, Herbert Solomon, David R. Howes.

Right, Miss Besse B. Day and Francis R. Del Priore reenact the problems of the statistician and the engineer in their skit "The Statistician and the Engineer Can Meet," performed for the Chemical Corps Engineering Command Second Annual Statistical Engineering Symposium at Army Chemical Center, Maryland.

DELAWARE The University of Delaware at Newark will offer three courses in statistics each starting with the fall term and continuing for two semesters. Courses ST450 and ST520 are on applied statistics. ST450 starting in the fall term covers the mean, standard deviation, simple and multiple correlation and tests of significance and reliability. The continuing course in the spring semester (ST520) covers correlation, analysis of variance, design of experiments and interpretation of results. The emphasis in these courses is on application rather than principle. Two courses in mathematical statistics will be offered in which the emphasis will be more on mathematical principle. The basic course, which is a prerequisite to the advanced course, covers the mathematical analysis of statistics including least squares and regression analysis. These courses are identified as ST401, for the fall term, and ST402 for the spring term. The more advanced course, (ST555 and ST503) covers least squares and analysis of variance.

THIRD ANNUAL SAN FRANCISCO BAY AREA QC CONFERENCE The Third Annual San Francisco Bay Area quality control conference will be held at Stanford University on Sept. 14. This will be a one day affair jointly sponsored by the Committee on Industrial Engineering of Stanford and the San Francisco Bay Area section. The keynote speaker, Walter Kassebohm, vice president of manufacturing, Marchant Calculators, will present "Quality control yesterday and today." Kenton Willhite of North American Aviation will speak on "Maximizing the quality control function." Other speakers include: Prof. Lieberman of Stanford; Robert Pappas of Ampex; Walter Hurd of National Motor Bearing; Alan Eagle of Stanford Research Institute; and Byron Blakeman, consultant. For reservations contact Professor Grant Ireson, Stanford University, Stanford, Calif.

LOUISVILLE Burr Stanton, education chairman, has completed plans for both an advanced and a basic quality control course. The advanced course will start in September.

STATE UNIVERSITY OF IOWA The fifteenth intensive full-time training course in quality control by statistical methods is scheduled by the State University of Iowa at Iowa City, Iowa, Oct. 16-26. This will be an introductory course which will follow the same general pattern of the previous basic courses.

A special session for executives is scheduled for the first day, Tuesday, Oct. 16. It will be devoted to an explanation of the aims and the possibilities of a quality control program and to outlining a procedure for the installation of such a program in the plants.

Instruction will be by lecture, demonstration, laboratory work, and evening question and problem discussion sessions, with the emphasis on practical interpretation throughout.

The fee of $100 per person includes text material, manuals, booklets, supplies, and university participa-

tion in the two 2-day follow-up clinics. Trainees will be expected to provide for their own transportation and living expenses. Room accommodations are available at the Jefferson Hotel in Iowa City. Make room reservations directly with the hotel.

Further inquiries concerning this course should be addressed to Prof. Lloyd A. Knowler, Chairman, Department of Mathematics and Astronomy, State University of Iowa, Iowa City, Iowa.

CASE INSTITUTE OF TECHNOLOGY OR COURSE Case Institute of Technology, Cleveland, Ohio, is offering a repeat session of a short course in operations research from Sept. 4-15. The objective of the course is to provide a short intensive survey of methods, techniques, and tools of operations research with emphasis on applications to business and industry. Case histories will be used extensively. The course will provide a foundation for development of technical competence but will not itself provide such competence. It is designed to produce an understanding of how and where operations research can be used.

The course prerequisites are research experience and sufficient knowledge of mathematics to understand mathematical symbolism. Mathematical derivations will not be emphasized.

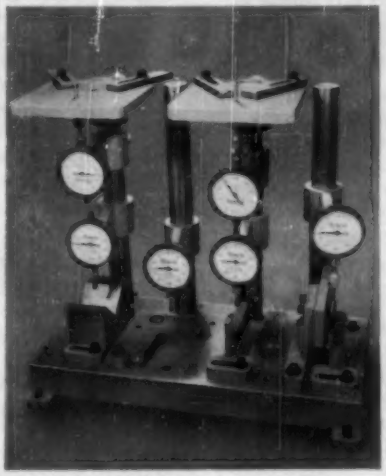
The course fee is $325 which includes all instructional fees, nine luncheons, six dinners or picnics, lecture notes, texts, and supplies. Living quarters will be available at a reasonable rate.

Registration is limited to the first 50 qualified applicants. Inquiries and registrations should be addressed to: W. W. Abendroth, Operations Research Group, Engineering Administration Department, Case Institute of Technology, 10900 Euclid Avenue, Cleveland 6, Ohio.

ST. LOUIS A second annual intensive course in statistical quality control is to be given at Washington University, Sept. 6-14.

WESTERN MASSACHUSETTS An advanced course in techniques of operative research will likely start the third week of September. Various phases of decision making will be reviewed with linear programming to receive emphasis. The course will be run in conjunction with the University of Massachusetts Extension and will require at least 20 participants.

CARNEGIE INSTITUTE OF TECHNOLOGY During the coming academic year Carnegie Institute of Technology will offer, in its evening program, two-semester credit courses in experimental design, probability and mathematical statistics, and statistical quality control. The courses will meet one evening per week, Monday, Wednesday, and Friday evenings respectively, 7:30-10:30 pm, Sept. 1956 through May, 1957. Registration



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ELEVENTH MIDWEST QUALITY CONTROL CONFERENCE

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for the courses will be Sept. 18-19 from 6:30-9:00 pm. For further information regarding graduate and undergraduate day courses, write to Prof. Edwin G. Olds, Department of Mathematics, Carnegie Institute of Technology, Pittsburgh 13, Pa.

11TH MIDWEST QC CONFERENCE OCTOBER 11-12

The Eleventh Midwest Quality Control Conference, with 15 technical sessions and an elementary training course, will be held Oct. 11-12 in the Hotel Leamington in Minneapolis, Minn.

Speakers in the technical sessions will cover recent developments in the relationships of quality control to management, research, automation, production, engineering, and sales.

Among the speakers will be Dr. William J. Youden of the National Bureau of Standards; Dr. Carl A. Bennett of Hanford Atomic Products Operation, General Electric; Ernest H. Robinson of Johnson & Johnson; and Dr. D. S. McArthur of Esso Research and Engineering Co.

General Chairman of the conference is Prof. Gayle McElrath of the University of Minnesota's Institute of Technology. The University is cooperating with the 22 Midwest sections of the society in presenting the conference.

The elementary training course is planned for foremen and supervisors and will stress practical applications of quality control in industry. The course, which will run concurrently with the technical sessions, will be conducted by Prof. N. H. Barnard, chairman of the department of mechanical engineering at the University of Nebraska; Prof. I. W. Burr, department of mathematics, Purdue University, and Prof. J. A. Henry, department of mechanical engineering at the University of Illinois.

A "statistical smorgasbord" is planned for the final session of the conference. A panel of professors will answer questions about individual quality control problems.

The program planned for wives of conference participants includes visits to the Walker Art Center, The Toni Company, and the Betty Crocker test kitchens at General Mills.

Registration fee for the two-day conference will be $20. Requests for advance registrations, or for additional information, should be mailed to the conference secretary, Robert Keane, P. O. Box 4337, Minneapolis 18, Minn.

TENTH NEW ENGLAND QC CONFERENCE OCTOBER 3-5

The Tenth New England Quality Control Conference will be held at the Hotel Sheraton-Kimball, Springfield, Mass., on October 3, 4, and 5. The theme of the conference will be "celebrating a decade of quality progress."

The program embraces a well-diversified selection of subjects which include the quality control functions of management, education, inspection, testing, laboratory, engineering, and advanced methods. Forty individual clinics will be conducted by nationally prominent speakers.

A very popular feature of the program includes management seminars led by such well-known authorities as Dr. J. M. Juran, Dorian Shainin, Warren Purcell, and Leonard Seder. This presents an unusual opportunity to sharpen your management thinking by discussing your specific problems.

A selection of plant tours has been arranged, including electrical, chemical and rubber industries.

This year a "TECHNICAL" session is planned for the ladies featuring "Charlie" Hudson, a founder of the society, and known nationally for his friendliness, good humor, and New England ancestry.

For registration form and program details, please write to M. W. Rogers, Registrar, c/o National Company, Inc., Malden, Mass.

5TH ANNUAL MEETING STANDARD ENGINEERS SOCIETY, OCTOBER 3-5

The theme of the Fifth Annual Meeting of the Standards Engineers Society to be held Oct. 3-5 at the Hotel Willard in Washington, D. C., will be "Standards—guides for tomorrow."

Sessions to be conducted include: standardization in the chemical industry; standards and the atomic energy field; the future trend of standards in the metals field; creative engineering and standards; progress of engine standardization; and what may be expected in the ABC unification effort. Also scheduled are discussions of screw thread standardization from the viewpoint of the manufacturer; the metrologist and the Government; progress in anti-friction bearing standardization; and management standards.

Outstanding speakers include: H. Thomas Hallowell, Jr., president of Standard Pressed Steel Co. and president of the American Standards Association; Dr. A. T. McPherson, associate director for testing, National Bureau of Standards; J. G. Morrow, chairman of the ABC committee of the Canadian Standards Association; and Frank P. Tisch, chief engineer of the Pheoll Manufacturing Co.

RUTGERS ALL-DAY CONFERENCE SEPTEMBER 8

The 8th Annual Rutgers All-Day Conference will be held on Saturday, September 8, on the New Brunswick, N. J. campus of Rutgers University. This SQC program is sponsored jointly by the Metropolitan Section, ASQC, and Rutgers University.

Four simultaneous sessions with eight speakers will be devoted to basic concepts of SQC for management, administrative applications in sales, production and inventory controls, electrical and mechanical industry applications, and SQC in pharmaceutical and chemical industries. These sessions are scheduled from 9:45-11:45 a.m.

Mr. Orlin C. Johnson, vice president in charge of production at the Bristol-Myers Hillside plant, will be the guest speaker at the luncheon session on the theme, "Quality control comes of age."

Three simultaneous afternoon sessions with seven speakers will deal with a panel discussion of management aspects of quality control, sampling, and advanced statistical techniques. These sessions are scheduled from 2:15-4:15.

Registration begins at 8:45 am in the Engineering Building. Registration fee is $5.00, including luncheon and a bound copy of Conference Proceedings. For further details, write to Miss Victoria Talley, Conference Secretary, University College, Rutgers University, New Brunswick, N. J.

"FOR MANY ARE CALLED, BUT FEW ARE . . ."

ALBUQUERQUE

The newly elected officers for the coming year are: P. H. Bircher, Sandia Corp., chairman; J. M. Wiesen, Sanida Corp., vice chairman; W. E. Caldes, Sandia Corp., secretary; L. R. Neibel, Sanida Corp., treasurer.

ALLENTOWN —BETHLEHEM Members of the section have elected the following officers for the 1956-57 year: chairman—D. S. Adams, Western Electric Co., Allentown, Pa.; vice chairman—B. Hammarstrom, Paulsboro Mfg. Co., Fullerton; treasurer—R. K. Wetherhold, Air Products Co., Emmaus; secretary—D. L. Hilder, Western El ctric Co., Inc., Allentown.

BALTIMORE The annual election of officers for 1956-57 was held during May and the following were elected: chairman—W. J. Aring, Koppers Co.; vice chairman—W. A. MacCrehan, Bendix Radio Division; treasurer—F. W. Cullen, National Plastics Products Co.; secretary—E. M. Glocker, Davison Chemical Co.

BINGHAMTON Theodore Lemoncelli of Endicott-Johnson Corp. was elected chairman of the section for the 1956-57 season. Other officers elected were: vice chairman—Charles H. Rubin, General Electric Co.; secretary—Joseph P. Cronin, IBM Corp.; treasurer—Joseph A. Jirauch, Ansco.

BUFFALO The following officers were chosen for 1956-57: Robert Stohr, engineering division, Carborundum Co., as Chairman; Al Kukla, supervisor of quality control, Aluminum Company of America, as vice chairman; Al Haven, supervisor of quality control, Trico Products Corp., as secretary-treasurer.

BURLINGTON Elected for 1956-57 are: chairman—Carlton F. Murphy, National Carbon Co., St. Albans; vice chairman—E. Howard Halpin, General Electric Co., Burlington; secretary—Robert O. Martel, Jones & Lamson Machine Co., Springfield; treasurer—Arthur M. Cesario, Jones & Lamson Machine Co., Springfield.

CHICAGO The section membership has elected their officers for the 1956-57 fiscal year. The officers are as follows: chairman—Robert I. Tenney, Wahl-Henius Institute; vice chairman—Eugene G. Freund, Victor Adding Machine Co.; treasurer—David Wadrow, Shure Brothers, Inc.; secretary—Alfred G. Schuber, Automatic Electric Co.

The Calumet sub-group of the section recently elected their officers for the coming fiscal year. The officers are as follows: chairman—Lee Fantz, The Anderson Co., Gary, Ind.; vice chairman of arrangements—Harold W. Williams, Inland Steel Co., East Chicago, Ind.; vice chairman of programs—Ralph Huth, Gary Sheet & Tin Mill, Gary, Ind.; secretary-treasurer—John Nelly, Socony Mobil Oil Co., East Chicago, Ind.

The newly formed Fox Valley sub-group has announced the election of their officers. They are: chairman—Christopher B. Wyatt, DuKane Corp., St. Charles, Ill.; vice chairman—Alfred F. Zornow, Continental Pkg. & Processing Co., Chicago, Ill.; secretary-treasurer—Harry E. Jahns, Burgess Norton Mfg. Co., Geneva, Ill.

ERIE Officers for the coming year will be: chairman—David F. Ferrel, Erie Resitor Corp.; vice chairman—Richard S. Albitz, Perry Plastics, Inc.; secretary—James R. Orcutt, General Electric Co.; treasurer—Clarence A. Haycox, Erie Resistor Corp.

HARRISBURG At the May meeting of the section, the following officers were elected tc serve for the coming year: Miles Nolte, chairman; Willard Smith, vice chairman; Steve Combs, secretary; Chet Betterman, treasurer.

HUNTSVILLE At the June 21 meeting the following were elected as 1956-57 section officers: chairman—Verne Reckmeyer; vice chairman—Bill Harrell; secretary-treasurer—Don Royston.

KANSAS CITY The section recently elected and installed the following officers: chairman—G. Michael Putthoff, Bendix Aviation; vice chairman—Fred W. Rohde, Westinghouse Electric; secretary—Frank E. Lair, Gustin-Bacon; treasurer—Terry B. Wilkenhorst, Ford Motor Co.

NEW HAMPSHIRE The recently elected officers for the 1956-57 season are: chairman—Wesley Gahagan, General Electric Co., Summerworth; treasurer—Cael Laurier, Scott & Williams, Laconia; secretary—Charles Currier, Scott & Williams, Laconia.

SAN FRANCISCO BAY AREA Results of the recent election of section officers for 1956-57 were announced at the May 31 meeting. Those elected were: chairman, Allan M. Hull, United Air Lines, San Francisco; vice chairman, John N. Colbeck, Ford Motor Co., San Jose; secretary, Allen Chop, San Francisco Army Ordnance, Oakland; treas-

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urer, George W. Varseveld, Stokely-Van Camp, Inc., Frozen Food Division, San Jose.

SOUTH BEND —MISHAWAKA The following are newly elected officers for the 1956-57 year: chairman—Robert G. Fitzgibbons, Bendix Products Div.-Missile Section, Bendix Aviation Corp.; vice chairman—Fred R. De Ferbrache, Jr., Defco Mechanical Lab.; secretary—Charles M. Makowsky, Bendix Products Div., Bendix Aviation Corp.; treasurer —Wayne F. Van Skyhawk, Royal Rubber Co.

STATE UNIVERSITY OF IOWA The annual election of officers was held with the following officers elected: president—H. R. Harrison, Collins Radio Co., Cedar Rapids, Ia.; vice president—C. C. Heldt, Sheaffer Pen Co., Fort Madison, Ia.; secretary-treasurer—Clarence O. Richards, Red Jacket Mfg. Co., Davenport.

TENNESSEE Newly elected section officers for 1956-57 are: chairman—John F. Boyd III, Bristol; vice chairman—Claude J. Powell, Elizabethton; secretary—Wallace W. Abbott, Lowland; treasurer —Mrs. Shirley T. Mackey, Oak Ridge.

TORONTO The four elected officers for 1956-57 are as follows: chairman—J. D. Gardiner, Photo Engravers & Electrotypers Ltd., Etobicoke, Ont.; vice chairman—H. C. Hilditch, Canadian General Electric Co., lamp dept., Toronto; secretary—M. J. O'Callaghan, British American Oil Co., Toronto; treasurer— M. F. Ward, A. V. Roe Aircraft Ltd., Malton.

TRENTON New officers for 1956-57 season are: chairman—Eugene B. McBride, Baldwin-Hill Co.; vice chairman—Richard M. Fox, Federal Inspector of Naval Material, Federal Building; secretary —Helmut E. Thierfelder, Baldwin-Hill Co.; treasurer— John F. Wargo, Ternstedt Div., GMC.

UTICA Elected officers for the 1956-57 season are: Paul Russo, chairman; James Adams, vice chairman; Robert Glaser, secretary; Al Cirillo, treasurer.

WESTERN MASSACHUSETTS New elected officers for the 1956-57 season are: chairman—Joseph G. Griffin of Westinghouse; vice chairman—Maurice Blew of Strathmore Paper; treasurer—Stuart G. Foote of American Bosch; secretary—Richard F. Goulart of Bigelow-Sanford Carpet Co.

WINNEBAGO The officers for the section for the 1956-57 term are as follows: chairman—Leland J. Manders, Charmin Paper Mills, Green Bay, Wis.; vice chairman—Willard Carlson, Whiting-Plover Paper, Stevens Point, Wis.; secretary-treasurer —Elmer Hauge, Kimberley-Clark Corp., Neenah, Wis.

WORCESTER Officers for year 1956-57 are: chairman—Warren Arnold, Jr., Draper Corp., Hopedale, Mass.; vice chairman—P. Roy Leaman, Bay State Abrasive Products Co., Westboro; secretary— Francis Olson, Norton Co., Worcester; treasurer—Edward W. Armstrong, Simonds Saw & Steel Co., Fitchburg.

MEMBERSHIP CORNER

Waco Section

The Waco section is still in its infancy (charter dated January 12, 1956), but we feel that the infant is a lusty one and shows great promise for the future. Membership is already 41 and every indication is that the number will be increased before the current fiscal year draws to a close.

In the summer of 1955, four members of the Society, living in and near Waco, Texas, decided that the time was at hand for a section to be formed here. At an informal meeting in July to consider the possibility of a Waco section, 22 persons were present, and at our August meeting there were 26 members present to help elect officers for the section.

Our plan, if such it can be called, for gaining additional membership for our section is based on three main points. The first is planning to have as good a program as possible for every monthly meeting. It seems idle to strive for new members unless both old and new members look forward to each meeting with the expectation of a program that will be both helpful and interesting to them. We have been very fortunate in obtaining good speakers for our programs; business has been kept to a minimum of time through good committee work; and each speaker has been good enough to allow a very enlightening question period at the close of his talk.

The second point in our membership effort is personal communication with various industrial firms in the area. The chairman of the membership committee, with others to help, has made a number of visits to such firms with the result that there are presently several more new prospects for membership at our next meeting.

The third point in our drive for members is service to members. We are having the first of a series of clinic sessions on the evening of our next monthly meeting (we meet on the fourth Monday night of each month). The clinic session will be one hour prior to the regular time. It is already apparent that the clinic sessions will be a good selling point for gaining new members.

We in the Waco section realize that we have far to go in equalling some of the older sections in membership campaigns, but at least we have made a start!

DIVISIONS

Chemical Division

The annual meeting of the division was held during the Montreal convention in the form of a luncheon session on June 8. The following officers were elected for the ensuing year: chairman—H. L. Wehrly; vice chairman—M. S. Renner; secretary—Brant Bonner; treasurer—D. H. Davis.

Encouraged by the enthusiastic response to the "Box Conference" held recently at Harvard Business School, plans are being formulated for a second such conference to be held at the University of Michigan in October.

Thirty-two persons were enrolled for the Rochester Institute of Technology course on quality control for the chemical industries, held in Rochester on June 17-18.

SIGNIFICANT DIFFERENCES

E. R. Harrall, 1955-56 chairman of the Baltimore section, was recently promoted from quality manager to factory manager of the Friez Instrument Div., Bendix Aviation Corp., Baltimore. Mr. Harrall has been active in quality matters with Bendix for the past five years.

Thomas B. Mullen was recently appointed quality control superintendent of the Pressware Plant at Corning Glass Works, Corning, N. Y. Mr. Mullen, Corning-Elmira section member, comes to quality control with five years experience as a field representative in Corning's technical service dept., and a degree in economics from St. Lawrence University.

The Delaware section congratulates Hillman Harris, section vice chairman, on a recent promotion in the chemical control department of Du Pont's Chambers Works. Hillman is now chief supervisor of statistical control in that department.

The July issue of *Journal of Agriculture and Food Chemistry* published a paper co-authored by Allan Thomas, treasurer of the Louisville section. The title of the Paper is "Determination and comparison of amino acid composition of yeast and of distillers solubles."

Dr. Paul K. Leatherman is now associated with Mallinckrodt Chemical Works, Uranium Division, 65 Destrehan. St. Louis 7, Mo.

Dr. J. H. Toulouse, Fellow of the society and the Toledo section, recently had a new honor bestowed upon him. Dael Wolfle, administrative secretary, has announced that Dr. Toulouse has been elected a Fellow of the American Association for the Advancement of Science. Dr. Toulouse is chief engineer of the quality & specifications department, Owens-Illinois.

M. F. Ward, membership chairman of the Toronto section, and formerly with International Business Machines Co., Ltd., is now with A. V. Roe Aircraft, Ltd. All the best in your new venture Merv.

Robert Glaser, formerly at General Cable, is now at General Electric. Bob, Utica section member, is doing experimental design work in the reliability group.

Arthur L. Becker, general manager of the IBM plant in Endicott, N. Y. has announced the appointment of Binghamton section member Michael C. Bugonian as manager of the quality control department in IBM's new plant in Rochester, Minn.

The Metals Technical Committee wishes to recognize the honor bestowed on two of its members by the American Iron and Steel Institute.

In May 1955, Arthur P. Woods, Jr. was awarded the American Iron and Steel Institute Medal for his paper "Some statistical methods used in studies of steel plant operations." In May 1956, W. T. Rogers was awarded the same medal for his paper "Coke quality and blast furnace operating practice."

These two committee members have as a result of these awards brought to the attention of the steel industry in particular and the whole metals industry, the importance of statistical quality control methods for the solution of problems pertaining to research, development and production.

Since these awards have resulted in recognition of the usefulness of quality control methods in the metals industry, the Metals Technical Committee officially commends and congratulates Arthur W. Woods, Jr. and W. T. Rogers for their excellent papers and the resultant awards.

At the 59th Annual Meeting of the American Society for Testing Materials held recently in Atlantic City, Simon Collier, director of quality control for the Johns-Manville Corp., New York, and Fellow of ASQC and the Metropolitan section, was presented with an Award of Merit in recognition of notable service in developing and standardizing methods for the chemical analysis of metals and for consistent administrative and technical support of Committee E-3 on chemical analysis of metals.

Bibliography

JOSEPH MOVSHIN, *Editor*

Assisted by the Editorial Committee, St. Louis Section, ASQC

BIBLIOGRAPHICAL

STATISTICAL METHODS IN CHEMISTRY, by John Mandel & Frederic J. Linning (National Bureau of Standards, Wash., D. C.)
(Analytical Chemistry, v. 28, n. 4, Apr. 1956, p. 770)

This article is somewhat bibliographical in nature in that it presents a brief review of some 218 articles on the application of statistical methods to the chemical industry. The authors outline various areas of application and list references applicable to each of these. Some comments on various of the references, their contents and application, is made on these sections. The sections included are: Accuracy & Precision of Methods and Equipment, Design of Experiments, Interpretation of Experimental Results, Study of Chemical Reactions and Laws, Miscellaneous Applications, Books, Tables and Abstracts. Three pages are used to list the 218 references cited.

APPLICATION— FOOD INDUSTRIES

TASTE COMPARISONS: TWO SAMPLES OR THREE?, by N. T. Gridgeman, (Div. of Applied Biology, Natl. Research Labs., Ottawa, Canada)
(Food Technology, v. 9, n. 3, Mar. 1955, p. 148-150)

An experimental test of the statistical power of three common types of test: (1) paired comparison (which sample is ——er?), (2) duo-trio (which of two samples is like a standard sample?), and (3) triangle (which of three samples is different?).

The probability of correct discrimination was estimated for the three tests applied to three foods: (1) ground beef, (2) tomato juice, and (3) a mixture of flavors. For all three foods, the paired com-

parison test showed the highest probability of correct discrimination. The results do not allow exact prediction of the relative costs of the three types of test, since the probability of correct discrimination is likely to depend not only on the test design but also on the taster, the material tasted, and the magnitude of the taste difference. Statistical aspects of this study are reported in *Biometrics*, v. 11, n. 1, Mar. 1955, p. 63-68.

SENSORY TEST METHODS. II. EFFECT OF PREVIOUS TESTS ON CONSUMER RESPONSE TO FOODS, by H. L. Hanson, J. G. Davis, A. A. Campbell, J. H. Anderson, and H. Lineweaver. (Western Utilization Research Branch USDA, Albany 6, Calif.) (Food Technology, v. 9, n. 2, Feb. 1955, p. 56-59)

A panel of 40 or more inexperienced judges tasted samples of scrambled eggs presented in various orders. Ratings (on a nine point scale) were influenced by the previous samples, even when two days elapsed between samples, with a tendency for succeeding samples to be rated lower. Magnitude of the effect may depend on the relative qualities of the samples tested. A test using two widely different foods (poor scrambled eggs and good turkey) showed no preceding-sample influence on the ratings.

DEVELOPMENT OF A SCALE FOR MEASUREMENT OF FOOD PREFERENCES, by L. V. Jones, D. R. Peryam and L. L. Thurstone (Food Research, v. 20, n. 5, Sept. 1955, p. 512-520)

A study of nine types of preference-rating scales, varying in length from five to nine intervals and using various combinations of phrases. Some were unbalanced and some had no neutral point. The scales were used to obtain ratings from soldiers on 20 foods.

The longest scale tested was the most sensitive. Reliability (correlation with re-test results) was about the same for all scales tested, but differed among the foods. Length of scale had no important effect on time required. Elimination of the neutral category seemed to be beneficial. Balance (equal number of positive and negative intervals) was not found to be an essential feature.

Scale values of 51 descriptive phrases were measured and reported, along with the standard deviation of each.

APPLICATION— MISCELLANEOUS

HOT PRESS GLUING OF HARDBOARDS TO DOUGLAS-FIR VENEERS WITH PHENOLIC RESIN ADHESIVES, by Frederic J. Shelton, (Tech. Div. Pacific NW Div., Reichold Chem., Inc., Seattle, Washington)

(Forest Products Journal, v. 5, n. 6, Dec. 1955, p. 388-395)

A study of effects of hardboard types and veneer moisture contents on the required press time and bond quality in gluing hardboards to Douglas-fir veneers. Analysis of variance tests are made of the time in minutes required to obtain an inner glue line temperature of a two-cycle boil test, of a two-cycle knife and shear test, and of a dry-knife and two-cycle boil test. Includes 12 tables of test results and analysis of variance.

STATISTICAL STUDY OF TANNING AND SAMPLING, by R. C. Putman, C. B. Crandall, and E. Facer, Jr., (United States Testing Co., Hoboken, N. J.)

(Journal American Leather Chemists' Association, v. 50, n. 11, Nov. 1955, p. 534)

On the basis of duplicate analyses from a number of bags in each of twenty lots of tanning, a statistical sampling plan is devised, yielding a constant allowable uncertainty of the sample average regardless of lot size. Data for use in preparing control charts are given and they are compared with A.L.C.A. "good agreement" values. Statistical techniques used include analysis of variance, components of variance, sample size calculations and control charts.

PHYSICAL PROPERTIES OF FATLIQUORED AND OF SOLVENT EXTRACTED LEATHERS, by V. Mattei and W. T. Roddy (Tanners' Council Research Laboratory, Univ. of Cinn., Cinn., Ohio) (Journal American Leather Chemists' Association, v. 51, n. 2, Feb. 1956, p. 67)

As a basis for studying and clarifying the influence oil has on the physical properties of leather, statistically designed experiments were carried out comparing the physical properties of fatliquored leather to solvent extracted leather. Data were analyzed for tensile strength, stitch tear strength, tongue tear strength, ball burst strength and hysteresis. The results are discussed from the viewpoint of the ability of the various tests to reflect the effect of fatliquoring.

SIGNIFICANCE OF THE RESULTS OF SOME PHYSICAL TESTS ON UPPER LEATHER, by J. R. Kanagy, (Natl. Bureau of Standards, Wash., D. C.)

(Journal American Leather Chemists' Association, v. 50, n. 3, Mar. 1955, p. 112)

The paper is essentially a study of the correlation between various physical tests commonly made on leather; viz, tensile strength, stitch tear, tongue tear, and bursting strength and of their relationship to the basic properties of the leather and to the type of tanning. Statistical methods include the use of the *t* test, near regression and correlation in addition to the application of statistical principles of design.

A COMPARISON OF GAS CHAMBER TESTS OF BOOKBINDING LEATHER WITH A LONG TIME ATMOSPHERIC EXPOSURE, by C. W. Beebe, R. W. Frey, and M. V. Hannigan, (Eastern Regional Research Laboratory, Phila., Pa.)

(Journal American Leather Chemists' Association, v. 51, n. 1, Jan. 1956, p. 20)

The paper describes the results of a test carried out over periods of 12 to 19 years for the comparison of the deterioration of bookbinding leather in natural use and in a gas chamber with high SO_2 concentration. The correlation is studied by non-parametric methods based on Kendall and Smith's ranking procedures. The calculations show that gas chamber tests lead to reasonably close predictions of the deterioration obtained in exposure of leather for 11 to 19 years.

ENGINEERING AND EXPERIMENTS

HOW STATISTICAL TECHNIQUES SOLVE METALWORKING PROBLEMS, by C. R. Smith (Metal Progress, v. 69, n. 2, Feb. 1956, p. 81-6, Mar. 1956, p. 76-8)

Multiple factor design and analysis of research experiment of the effects of alloying agents of

Selected references in the Bibliography of *Industrial Quality Control* are obtained from the following sources:

The International Statistical Institute, *International Journal of Abstracts on Statistical Methods in Industry.*

titanium were used by Mallory-Sharon Titanium Corp. Through these techniques it was possible to minimize the amount of experimental data needed to obtain the best methods of processing the material.

INDUSTRIAL MANAGEMENT

QUALITY PLANNING AND CONTROL, by Frank M. Gryna, Jr., (Asst. Prof. of Stat. Quality Control, Rutgers University)
(The Journal of Industrial Engineering, v. VII, n. 3, May-June 1956, p. 122-125)

This article discusses the elements and techniques of planning and control as applied to the quality function. Included as planning elements are:

Realistic specifications.

Specifications that are clearly stated.

Operating procedures that are capable of meeting the desired quality level.

These are further broken down to the techniques and areas involved. Under the control phases the following are discussed:

Realistic amount of inspection with the results reported in useful form.

Staff activity that analyzes inspection reports and customer complaints to make recommendations for guiding overall company efforts on the quality problem.

Staff activity that can help the production function to find and correct the causes of bad work.

Basically, the article stresses the importance of planning as a part of the control function and the necessity for using operational information for planning and control purposes.

STATISTICS

THE OPERATING CHARACTERISTIC CURVE FOR SEQUENTIAL SAMPLING BY VARIABLES WHEN THE PRODUCER'S AND CONSUMER'S RISKS ARE EQUAL, by Norman R. Garner
(Journal of the American Statistical Association, v. 51, n. 273, Mar. 1956, p. 108)

SOME THEORETICAL ASPECTS OF THE LOT PLOT SAMPLING INSPECTION PLAN, by Lincoln Moses
(Journal of the American Statistical Association, v. 51, n. 273, Mar. 1956, p. 84)

INVESTIGATING THE PROPERTIES OF A SAMPLE MEAN BY EMPLOYING RANDOM SUB-SAMPLE MEANS, by Howard L. Jones
(Journal of the American Statistical Association, v. 51, n. 273, Mar. 1956, p. 54)

ON SIMPLIFICATIONS OF SAMPLING DESIGN THROUGH REPLICATION WITH EQUAL PROBABILITIES AND WITHOUT STAGES, by W. Edwards Deming
(Journal of the American Statistical Association, v. 51, n. 273, Mar. 1956, p. 24)

KEEPING MOMENT-LIKE SAMPLING COMPUTATIONS SIMPLE, by John W. Tukey
(The Annals of Mathematical Statistics, v. 27, n. 1, Mar. 1956, p. 37)

A "MIXED MODEL" FOR THE ANALYSIS OF VARIANCE, by Henry Scheffe
(The Annals of Mathematical Statistics, v. 27, n. 1, Mar. 1956, p. 23)

OPERATIONS RESEARCH

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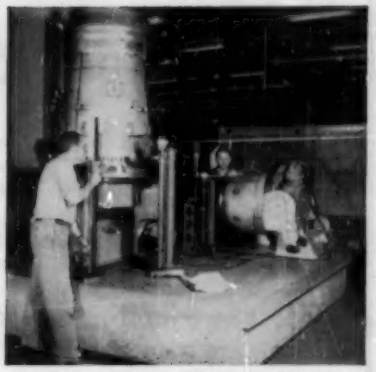

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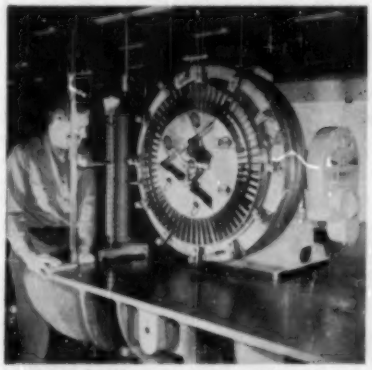

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SEARCH, by James W. Thompson, PE., (Chief Ind. Eng., Argus Cameras, Inc.)
(The Journal of Industrial Engineering, v. VII, n. 3, May-June 1956, p. 101-106)

The author discusses the area of overlap of Industrial Engineering and Operations Research. Specifically, the following are discussed:

1) "The sometimes parallel and sometimes diverging aspects of Industrial Engineering and Operations Research approaches to a problem.
2) Operations Research as a natural addition to the Industrial Engineering group.
3) The value of Operations Research to the Industrial Engineering group at Argus Cameras."

The author points out that many problems and techniques are common to both. The method of analysis and the scientific approach have much in common. The author discusses many of the areas of overlap both from the problem and technique standpoint.

A CHALLENGE TO OPERATIONS RESEARCH, by George L. Parkhurst

APPLICATIONS OF GAME THEORY IN FIGHTER VERSUS BOMBER COMBAT, by T. E. Caywood and C. J. Thomas

ON A CONGESTION PROBLEM IN AN AIRCRAFT FACTORY, by Georges Brigham

A NON-NUMERICAL APPROACH TO PRODUCTION SCHEDULING PROBLEMS, by Sheldon B. Akers, Jr. and Joyce Friedman

SYMPOSIUM ON APPLICATIONS OF OPERATIONS RESEARCH TO URBAN SERVICES, A DETERMINATION OF THE OPTIMUM LOCATION OF FIRE-FIGHTING UNITS IN NEW YORK CITY, by David Valinsky

EXPECTANCY OF MULTIPLE VEHICULAR BREAKDOWNS IN A TUNNEL, by Leslie C. Edie

EVALUATING THE ADEQUACY OF AIRPORT PARKING LOTS, by Frederick V. Hurst, Jr.

ENGINEERING STUDIES OF URBAN TRAFFIC FLOW, by Henry A. Barnes
(Journal of the Operations Research Society of America, v. 3, n. 4, Nov. 1955)

STATISTICS AND OPERATIONS RESEARCH, by Philip M. Morse

OPERATIONS RESEARCH IN PRODUCTION CONTROL—A PROGRESS REPORT, by A. Vazsonyi

APPROACHES TO OPERATIONAL PROBLEMS IN STREET AND HIGHWAY TRAFFIC—A REVIEW, by D. L. Gerlough and J. M. Methewson.

SHOCK WAVES ON THE HIGHWAY by Paul I. Richards

CRITERIA FOR THE SELECTION OF WATER-RESOURCE PROJECTS, by Roland N. McKean

THE TRAVELING-SALESMAN PROBLEM, by Merrill M. Flood

MACHINE REPAIR AS A PRIORITY WAITING-LINE PROBLEM, by Thomas E. Phipps, Jr.

A POLAR-PLANIMETER METHOD FOR DETERMINING THE PROBABILITY OF HITTING A TARGET, by G. R. VanBrocklin, Jr., and P. G. Murray

PREDICTION OF ODD-LOT STOCK TRANSACTIONS, by Herbert K. Weiss

PRODUCTION SCHEDULING BY THE TRANSPORTATION METHOD OF LINEAR PROGRAMMING, by Edward H. Bowman

A COMPETITIVE-BIDDING STRATEGY, by Lawrence Friedman
(Journal of the Operations Research Society of America, v. 4, n. 1, Feb. 1956)

OF HORSELESS CARRIAGES, FLYING MACHINES, AND OPERATIONS RESEARCH: A TRIBUTE TO FREDERICK WILLIAM LANCHESTER (1868-1946), by Joseph F. McCloskey

A MONTE CARLO MODEL OF LANCHESTER'S SQUARE LAW, by Ivan Driggs

MULTIPLE FACTOR BREAK-EVEN ANALYSIS: THE APPLICATION OF OPERATIONS-RESEARCH TECHNIQUES TO BASIC PROBLEM OF MANAGEMENT PLANNING AND CONTROL, by Robert Stanley Weinberg

A GRAPHICAL SOLUTION OF THE TRANSPORTATION PROBLEM, by Marcello L. Vidale

WAITING-LINE THEORY AS A MANAGEMENT TOOL, by W. R. Van Voorhis

THE DETERMINATION OF REQUIREMENTS FOR WAREHOUSE DOCK FACILITIES, by Donald H. Schiller & Marvin M. Lavin
(Journal of the Operations Research Society of America, v. 4, n. 2, Apr. 1956)

BOOK REVIEWS

W. D. Baten, Editor

MODERNE KONTROLLE (Modern Controls) in German; by H. Lustig, J. Pfanzagl, L. Schmetterer; published by Osterreichische Statistische Gesellschaft (Austrian Statistical Association), Vienna, Rathausstrasselg, Austria, Second Edition, 1956; 81 pages; 8 x 11; paperbound.

A compact and easy-to-read volume, covering the statistical tools of frequency distribution, averages, significance tests, control charts for averages, ranges, and medians; binomial and Poisson applications to control charts; and single and double sampling.

—NLE

WOOL RESEARCH, Volume 3: TESTING AND CONTROL IN THE WOOL INDUSTRY (no individual authors on title); published by Wool Industries Research Association, Torridon, Headingley, Leeds 6, England, 1955; 277 pages; 7 x 10.

A comprehensive work on the most up to date tools of testing and control of quality in the woolen industry. Contents cover the following; measurement and control of humidity in testing rooms, strands, average weight and its control, year strength measurement, twist determination, silver and slubbing variation, fabric tests for strength, wear, thickness and air permeability, tests for water repellency, nomograms, mill experiments and operational research.

The multitude of practical examples and useful data attest to the experience of the very competent group of over a dozen contributors to this excellent and valuable treatise. It is only regrettable that a similar volume does not as yet exist also for other spinning systems, such as the cotton system or synthetic filament and the worsted system of production.

—NLE

AN OUTLINE OF STATISTICAL METHODS FOR USE IN THE TEXTILE INDUSTRY; by A. Brearley and D. R. Cox; published by Wool Industries Research Association, Torridon, Headingley, Leeds 6, England, Third Edition, 1953; 77 pages; 6 x 10; paperbound.

A useful little manual, showing in compact form numerous practical applications of statistical quality control in woolen spinning and knitting. Included are not only the usual tools of frequency distributions and associated measures and control charts, but also significance tests and the design of experiments.

—NLE

STATISTISCHE QUALITATS KONTROLLE IN DER BAUMWOLL SPINNEREI (Statistical Quality Control in Cotton Spinning) in German; by W. Masing; published by Kohlhammer Verlag, Stuttgart, Germany, 1955; 149 pages; 9 x 6; paperbound.

This book covers primarily the application of control charts in a carded cotton mill, from opening and picking through spinning. Linear correlation and two-factor variance analysis are also covered briefly. The emphasis of the book remains heavily on the tools of analysis and construction of control charts, without going into the case histories of actual quality improving or cost saving results that may be achieved with these tools. Most examples are taken from picking and spinning, with very little material on the intermediate stages of carding, combing, drawing, and fly-frame processing.

Illustrative material and tables, such as the table of F-values, are used without giving source credit. This seems to be an unfortunate omission. There is, however, furnished a bibliography guiding the reader to further German and English language studies on statistical quality control as applied to textile processing.

—NLE

What's New?

ROY A. WYLIE, *Editor*

When inquiring about "What's New?" items, please mention INDUSTRIAL QUALITY CONTROL

John Chatillon & Sons, New York 38, N. Y., have announced a new series of Push Pull Dynamometer scales for capacities from 1 pound to 600 pounds. The new Chatillon Push Pull Dynamometers are the only dial scales wherein push and pull can be measured from the same shaft. The scale can be mounted vertically, shaft down, or horizontally. It can also be mounted vertically with shaft up on special order. It is suggested that these units may find applications in spring testers, radio socket testers, torque testing and Dynamometer testing.

★ ★ ★

The Sheffield Corp., Dayton 1, Ohio, have announced a new Micro-Hardness Tester. This instrument is a combination metallurgical microscope and Micro-Hardness Tester of non-destructive type with load-weight range from 25 to 1000 grams, and requires only one minute for a complete test cycle. Interchangeable vise accessories permit this instrument to be used for testing small precision ground or lapped parts, small diameter wires, very thin materials or material coatings, thin sheet stock, cutting tool edges and ball bearings. It is a practical instrument for a shop as well as laboratory, since it is fast and easy to operate. A green light in the head of the instrument shows when the indenter is in contact with the work and a red light indicates when load cycle is complete. Vertical capacity is 2⅜ inches and the maximum spread of standard vise jaws is $1\frac{11}{16}$ inches. Surface finishes of 40 r.m.s. or less can be inspected and indentations of 0.0004 inches or smaller can be measured to an accuracy of 0.00008 inches. The spot to be indented can be located to an accuracy of 0.0002 inches. The work piece is raised to the indenter by handwheel. A specially designed loading system, with the load applied in a direct vertical motion perpendicular to the work, eliminates indenter side thrust and deformed indentations which might cause incorrect reading of hardness value. When the instrument is used as a metallurgical microscope, the interchangeable objective lenses provide magnifications of 200x and 400x. A camera can be attached to the eyepiece for making photomicrographs.

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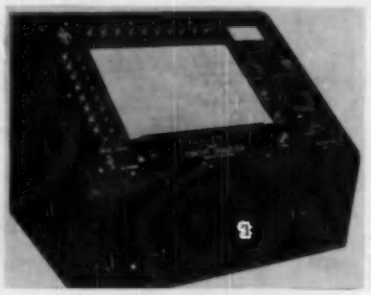


An automatic electrical Circuit Analyzer has been designed and is now being manufactured by the Electronics Division of **DIT-MCO, Inc.**, 911 Broadway, Kansas City, Mo. This unit will be of interest to companies who manufacture, maintain or overhaul products which include complex electrical circuitry. Model 80 Analyzer will test 80 circuits in about 8 seconds; Model 200 will test 200 circuits in 20 seconds and multiplier units are available to increase capacity up to 1600 circuits. The tester itself never has to be modified. Adapting it to test any cabling system or panel assembly requires only an adapter cable. The Circuit Analyzer can be quickly adapted to test any electrical cable system at any stage of production, modification or maintenance. It will test for all types of errors resulting from incorrect connections, short resistance between circuits and insulation resistance. In addition, it can functionally test such devices as relays, solenoids, actuators, panel lights, resistors, and other resistance-type devices. It can also test circuits connected together in various ways, such as switches, relay contacts, or a common point at a terminal, such as a grounding lug. The circuits in the unit under test

can be rearranged by switching mechanisms in the unit, and the tester will automatically check the new arrangement. Non-technical personnel can master the operation of the Circuit Analyzer in 30 minutes or less. The machine uses a visible matrix reference chart which allows the operator to pinpoint errors and go directly to them for correction without reference to an instruction manual. Lights on the machine's control panel indicate the type of error. In order to put the Analyzer in operation the operator merely installs the proper matrix chart, plugs in an adapter cable, and flips a switch. The test then proceeds automatically until an error is located. The machine is built of the same type components as those used on automatic telephone systems. Most are pluggable.

★ ★ ★

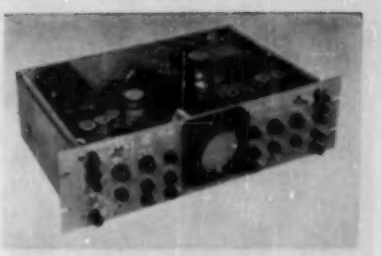
Sperry Products, Inc., Danbury, Conn., are sending their Mobile Demonstration Unit on a 48-state tour of American industrial centers. This unit made its debut at the A.S.Q.C. convention in Montreal in June. Visiting industrial plants for demonstrations conducted by Sperry field engineers, the caravan functions as a traveling laboratory in which metallurgical, quality control and production engineers may learn methods and potentialities of nondestructive testing with ultrasonic instruments. The tentative travel schedule includes Toledo, Cleveland, Dayton, Cincinnati, Detroit, Chicago, Milwaukee, Spokane, Seattle, Portland, San Francisco, Los Angeles and San Diego.

★ ★ ★

The "Master" dial indicator checker, a quick, easy-to-use and completely dependable method of checking the accuracy of all A.G.D. indicators is now available from **Petz-Emery, Inc.**, Pleasant Valley, N. Y. It provides large users of dial indicators with a reliable means of periodic checking, enabling them to check both new and repaired indicators for accuracy. In operation, the accuracy of the dial indicator is checked through a range up to one inch against a large calibrated wheel eight inches in diameter with a micrometer barrel as its hub. Graduations of 0.0001 inches are marked on the outer rim of the wheel and may be lined up with a hairline sight. The indicator contact point is set against the micrometer spindle by means of a vernier zero adjustment which does not require locking. The user turns the wheel for a given distance and checks the resultant reading on the indicator. Readings to 0.00002 inches can be easily estimated.

★ ★ ★

Development of an extremely compact, low frequency industrial oscilloscope has been announced by **Hycon Electronics, Inc.**, Pasadena, Calif. The instrument is sensitive to both direct and alternating current voltages and has identical horizontal and vertical amplifiers to assure accurate phase angle measurement. The new oscilloscope features usable response up to 500 kilocycles and is "flat" within three decibels at from 0 to 300 kilocycles. Built-in calibration voltage enables the user to measure the amplitude of voltage while it is being observed. The instrument is suitable for mounting in the standard 19-inch relay rack or cabinets. The cathode ray tube face is flat to minimize distortion.



★ ★ ★

A new Tera-Ohmmeter for making resistance measurements up to 5000 million megohms (5,000 tera-ohms) is available from the **Federal Telephone and Radio Co.**, 100 Kingsland Rd., Clifton, N. J. The instrument is similar in most respects to the type FT-H previously announced except that it has ten times the sensitivity. The FT-H4 includes a test voltage

NEW

Bausch & Lomb

SURFACE COMPARATOR

- checks surfaces and finishes quickly
- eliminates guesswork
- saves time and money

Here's a compact, portable and extremely accurate instrument for comparing surfaces and finishes with your "reference standard." The man at the machine, the foreman and quality control man can tell instantly if the work is rougher or smoother than standard . . . guesswork is eliminated, time is saved and quality is kept at a high grade. The Surface Comparator is the first instrument of its kind . . . the perfect answer to metal surface comparison inspection. Net price, $30.00.

WRITE for complete details. Bausch & Lomb Optical Co., 50208 Lomb Pk., Rochester 2, New York.

BAUSCH & LOMB

SINCE 1853

which is continuously variable from 100 to 1000 volts. The new instrument is of particular value in such applications as the development of special insulating materials or wherever it is desired to measure extremely wide ranges (20 megohms to 5,000 million megohms) resistance. Specifications for the Type FT-H4 are as follows:

Range—20 megohms to 5,000 million megohms in 6 ranges.

Test voltage—continuously adjustable from 100 to 1000 volts d.c.

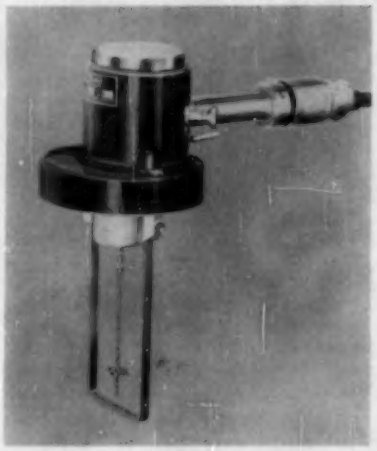
Accuracy—3 percent in scale center.

Test samples—grounded, ungrounded, or with guard ring electrode.

Dimensions—height, 18.9 inches; width, 21.3 inches; depth, 9.1 inches.

Weight—44 lbs.

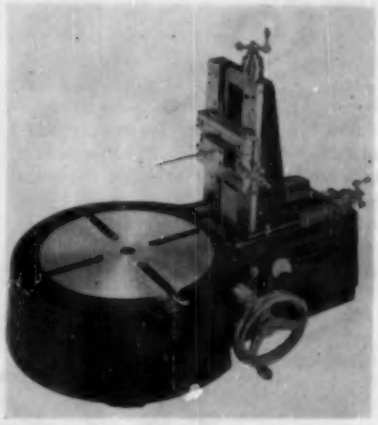
★ ★ ★



Brookfield Engineering Laboratories, Inc., Stoughton, Mass., have announced the introduction of the new Brookfield Explosion Proof Viscometer. This unit is designed for use in Class I, Group D locations and has the same accuracy and versatility of all Brookfield instruments. The motor for the new Explosion Proof Viscometer is completely encased in a "machined from the solid" aluminum case, and all immersible parts are stainless steel. The explosion proof features have been approved by the Underwriters' Laboratories for all models.

★ ★ ★

A new method of checking and inspecting contoured surfaces by means of a direct measuring instrument has been announced by **Summit-Roberts Products, Inc.**, 830 New York Ave., Toledo, Ohio. The instrument, known as the Contour-O-Scope, checks dimensional radial accuracy of parts such as impellers, expellers, inducers, exducers, diffusers, nozzles, turbine wheels, blades, two and three-dimensional cams, and many other parts having contoured surfaces. It eliminates need for intricate set-ups and layouts. Summit-Roberts Products, Inc. have used the Contour-O-Scope



for several years in the development and production of parts for jet, gas and steam turbine, precision forgings and other allied fields. Interest shown by visiting industrial personnel has resulted in its availability for general use. Complete information is available by writing to the manufacturer.

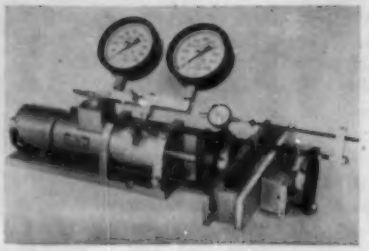
★ ★ ★

Pacific Scientific Co., 6280 Chalet Drive, Bell Gardens, Calif., announces a new flexural fixture permitting precise testing of honeycomb and plastic materials has been incorporated in the Cal-Tester Tensile Testing Machine to give it added versatility. Adaptable for tension, compression, or flexural testing when fitted with the proper accessories, the Cal-Tester provides a

QUALITY CONTROL ENGINEER

A fully integrated quality control program is being planned for a new sanitary ware ceramic plant being built at Plainfield, Conn. This man will plan all inspection procedures, tests and experiments for defect prevention, quality assurance procedures, the application of statistical tests, and the planning of executive reports on quality. Preliminary training will be given at our plant in New Orleans, Louisiana.

Applicants must have had engineering training or equivalent experience in the field of modern industrial quality control. Kindly furnish resume of personal data and experience, including snapshot if available. Address replies to Personnel Administrator, American-Standard, P. O. Box 149, Danielson, Conn.



constant rate of strain and load for testing metallic or non-metallic materials in rod, strip or sheet form. It is operated hydraulically by a direct-connected, reversible motor-driven pump. The action of the Cal-Tester is taken directly from a ram or 3 inch diameter piston. Load ranges of 1000 and 5000 lbs. are divided into increments of 5 and 20 pounds on two 6 inch Bourdon tube gages. Other capacities from 200 to 10,000 lbs. are available. Each range is guaranteed to be accurate within one percent of the indicated load.

★ ★ ★

The Jerpbak-Bayless Co., Solon Road, Solon, Ohio, have announced a new portable spacing comparator. The comparator will check spacing on flat and circular thread rolling dies; thread chasers; circular and flat form tools; wheel crusher rolls; gear racks; broaches; jet turbine blades and all threaded products. Range is 1/16 minimum—5½ inch maximum. The comparator consists of two work-contact points having horizontal travel. Measurements made by these contact points are transferred to a dial built into the top of the comparator. The dial movement is fully encased for protection against damage.

★ ★ ★

Nuclear Corporation of America, Inc., 4219 Empire State Building, New York 1, N. Y., have announced a new series of Beta radiation, non-contact thickness gages, under the tradename of Atom-At, for the continuous measurement and quality control of sheet paper and board, plastics, rubber, metal foil and strip, coatings and laminates. Five basic types of gages are available for a wide range of materials and applications:

(1) The basic Transmission gage for paper, paperboard, metal foils and strip, plastics, rubber and other sheet materials.

(2) The Backscatter gage to measure coatings such as paint, lacquer, adhesives, rubber and other moving materials which are accessible from only one side.

(3) The Differential gage for measuring coatings on thin materials.

(4) The Multiple Head Transmission gage for greater widths of the same materials.

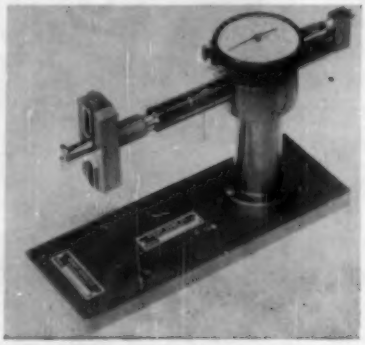
(5) The Transverse Profile portable gage which measures thickness across the entire width of a sheet.

The range of weights or thicknesses that can be measured cover all normal manufacturing needs.

★ ★ ★

Spitfire Tool Co., 2931 North Pulaski Rd., Chicago 41, Ill., have introduced the Spitfire Mono-Light for flatness measurements. The unit contains a helium lamp and is compactly designed for easy portability. When closed it is 5½ x 6 x 8¼ inches. The opal glass lighting area is 4⅓ x 7½ inches. The helium light source lasts indefinitely. Price of the unit is $79.50 f.o.b. Chicago.

★ ★ ★



Rimat Gage Co., 21 West Dayton St., Pasadena, Calif., has announced its Thousand Series Dial Bore Gages. One basic gage covers a range from ¼ to over 5 inches. Economical interchangeable tips are utilized for checking bores, shallow counterbores, grooves, threads, reliefs, splines and gears. The basic gage is a pistol-grip design, light, rugged and easy to hold. Retractable tips have a straight-line expansion of 0.260 or 0.400 inches at any setting. Indication is on a dial indicator calibrated to 0.0001 inches. Micrometers, gage blocks or rings may be used for master settings. Normally furnished as a portable instrument, the Thousand Series Gage can be converted to a bench instrument easily and economically.

★ ★ ★

The George Scherr Co., Inc., 200 Lafayette St., New York 13, N. Y., are importing the new improved "Puppitast" Universal Test Indicator. This indicator features a shock-proof movement, exceptional sensitivity and accuracy. Contact points now have a threaded base making it possible to screw them into a rotating axis at the tip of the holder. Model A Indicator reads in 0.0005 inches with a total range of 0.030 inches and Model B reads in 0.0001 inches with a total range of 0.010 inches. The dial is finished in a non-reflecting material and the bezel is finished in dull chrome. Model A sells for $26.75 and Model B for $34.75 including a wooden case, a Universal Shank and a ¼ inch bushing. Further specifications, illustrations and description are supplied in a one-page circular available on request.

The New

"DERMITRON"

NON-DESTRUCTIVE THICKNESS TESTER

FOR METALS ON METALS
NON-CONDUCTORS ON METALS
METALS ON NON-CONDUCTORS

- FAST
- ACCURATE
- PORTABLE
- COMPACT
- DIRECT READING

You can have 100% inspection of production of nearly any possible coating on almost any base. The first and only non-destructive tester which gives fast, accurate, direct readings of such combinations as silver on brass, copper on zinc, metallizing on plastics, paint on metals—without the use of chemicals.

WRITE FOR FULL INFORMATION

Patents Applied For

UPA

UNIT PROCESS ASSEMBLIES, INC.

75 EAST FOURTH STREET
NEW YORK 3, N. Y.

A new line of compound microscopes under the tradename Microstar has just been announced by **American Optical, Instrument Division,** Buffalo 15, N. Y. The Microstar features interchangeable and reversible inclined monocular, binocular and trinocular bodies. The stage and specimen are focusable to the objective by coarse and fine adjustments. The body tube height and eye level remain constant. Variable autofocus minimizes possibility of damage to objective and specimen. Both left-hand and right-hand mechanical stages are available. All major adjustments are located in substage zone for ease of manipulation. A wide variety of models is available to meet specific needs. Industrial microscopists will be interested in the building block principle incorporated in the new Microstar laboratory microscopes. Models can be modified by the addition of interchangeable parts to satisfy broader applications as the need arises. A more advanced model is offered with a built-in base illuminator, a trinocular body and an attached 35mm camera for on-the-spot color photomicrography.

★ ★ ★

The DoALL Co., 254 North Laurel Ave., Des Plaines, Ill., have announced a new set of standards for precision gage blocks. The following items are included in the standard:

(1) Production of new grade of gage blocks accurate to plus or minus one millionth of an inch.

(2) Production of an optical finish for gage blocks of 0.09 microinch.

(3) Discontinuation of the production of "B" grade blocks as inadequate for today's dimensional requirements.

(4) "A" grade blocks will be sold at "B" grade prices.

(5) An actual size calibration certificate will be provided for each gage block.

All blocks will be available in square or rectangular shape.

DO YOU HAVE A QUALITY CONTROL PRESENTATION PROBLEM?

QUALITY CONTROL AIDS ARE THE ANSWER

Make your presentation more forceful and understandable by the use of these aids.

QUINCUNX
... This device permits your audience to visualize the creation of a normal distribution pattern as well as the results of variables sampling. All beads are self-contained; nothing to drop out. Done in attractive mahogany complete with zipper carrying case.

ATTRIBUTE SAMPLING DEMONSTRATOR
... Complete unit consists of transparent plastic container, opaque colored beads, and wood paddles permitting easy identification of beads at a distance.

SIMULTATORS
... To demonstrate control chart plotting and shift of distribution pattern.

Lightning Calculator Co.
Box 6192
St. Petersburg Beach 6, Fla.

NEW LITERATURE AVAILABLE

LANCO Apparatus Review No. 6, published by Arthur S. LaPine & Co., Chicago 29, Ill., describes and illustrates 1955's best sellers in the line of Laboratory apparatus. A separate 4-page section introduces Harleco volumetric solution concentrates.

The Taft-Peirce Manufacturing Co., Woonsocket, R. I., have published a bulletin entitled "6 Special Ways to Air Gage for Lower Costs, Higher Production." The bulletin describes six unusual applications of air gaging to production and inspection problems.

A brochure describing the Numar Model M-2 precision Gaussmeter, an instrument for the measurement of homogeneous magnetic fields, is available from Nuclear Magnetics Corporation, 154 Boylston St., Boston, Mass. The Gaussmeter, based on the principles of nuclear magnetic resonance, can be used for measuring magnet field strength, calibrating laboratory magnets, plotting magnetic field contours and gradients, and for educational demonstrations of nuclear magnetic resonance.

Persons interested in learning more about Infrared Spectroscopy can now obtain a handy package of Beckman reprints on the subject from Beckman Instruments, Inc., Fullerton, Calif. The reprints serve as an introduction into the ever-growing field of Infrared Spectroscopy. Included in the package are the following articles:

"Infrared Spectroscopy," by R. Bruce Scott and J. M. Vandenbelt of the Parke, Davis & Co.

"Spectra-Structure Correlations in the Infra-Red Region," by N. B. Colthup, Stanford Research Laboratories

Analysis of Hydrocarbons via Infrared Spectrophotometric Instruments," by R. Pat Conner and W. M. Ward of Beckman Instruments

"Ultraviolet and Infrared Spectrophotometric Analysis of an Insect Repellent Mixture," by Warren A. Sassaman and S. P. Cohen of the Pioneering Research Laboratories, U.S. Army Quartermaster Corps.

Federal Products Corp., 1144 Eddy St., Providence 1, R. I., has issued a new edition of the Dimensionair Catalog No. 56D. Among the new items listed in the Dimensionair Catalog are Matched AirProbes; the Differential Air Meter for direct reading of taper and parallelism measurements; and the Probe-X, a new Air attachment for the Arnold Continuous Grinding Gage.

Hastings-Raydist, Inc., Hampton, Va., have published a new brochure describing their line of air-meters, vacuum gages, Manometer-Flowmeters and electronic standard cells.

POSITIONS AVAILABLE

Address all replies to box number references to: American Society for Quality Control, Room 6197 Plankinton Bldg., 161 W. Wisconsin Ave., Milwaukee, Wis.

QC MANAGER—In the leading company of a new primary industry. Requires thorough knowledge of SQC and substantial QC management experience in metal manufacture. Company headquarters—New York City; most plants in East; some travel to West Coast required. Please send resume to Box 13P1 at above address.

QUALITY CONTROL ENGINEER

With knowledge of gage design, trouble shooting and inspection methods used in mass production. Experience in statistical quality control desirable. Salary $7,000 to $8,000. Ronson Corp. of Pa., 250 Harris St., East Stroudsburg, Pa.

IQC

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QUALITY CONTROL ENGINEERS

A new fully integrated quality control program is being set up at Unit Plant which is manufacturing chrome plated brass plumbing fittings. Under the direction of the Quality Control Engineering Supervision these Engineers will plan all inspection procedures, tests and experiments for defect prevention, quality assurance procedures (audit and check inspection), the application of statistical tests, and the planning of executive reports on quality. Applicants must have had engineering training or equivalent experience in the field of modern industrial quality control. Kindly furnish resume of personal data and experience, including snapshot if available. Address replies to Personnel Administrator, American-Standard, 1541 South Seventh Street, Louisville 8, Kentucky.

POSITIONS WANTED

Address all replies to box number references to: American Society for Quality Control Room 6197 Plankinton Bldg., 161 W. Wisconsin Ave., Milwaukee, Wis.

Position wanted as quality control supervisor to set up and supervise a new and integrated quality control program. Five years experience in industry as a supervisor of statistics section doing statistical quality control and designing experiments. Degree in mathematics and statistics. Salary open. Please reply to Box 13B1 at the above address.

CONSULTING SERVICES

Responsibility of the American Society for Quality Control, Inc., for Consulting Services advertising is limited to certification that advertisers hold the grade of membership in the Society stated in their advertisements. Qualification requirements for the several grades of membership are set forth in the Constitution of the Society.

QC Planning — Defect Prevention

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FELLOW, ASQC
267 HAWTHORNE ST.
MALDEN, MASS.
MAlden 4-5446

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QUALITY CONTROL SPECIALIST
Senior Founding Member ASQC
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2480 16th Street N. W.
Washington 9, D.C., AD. 4-4711
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5410 Wilshire Boulevard
L. A. 36, Calif., WE. 8-0121

Statistical Methods
Inspection Surveys
•
Serving Industry On East and West Coast Areas

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1154 Book Building
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Telephone
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QUALITY CONTROL ENGINEER

A new fully integrated quality control program is being set up in a ceramic plant, which is manufacturing sanitary ware. This man will plan all inspection procedures, tests and experiments for defect prevention, quality assurance procedures, the application of statistical tests, and the planning of executive reports on quality. Applicants must have had engineering training or equivalent experience in the field of modern industrial quality control. Kindly furnish resume of personal data and experience, including snapshot if available. Address replies to Personnel Administrator, American-Standard, P. O. Box 8237, New Orleans 22, Louisiana.

YOUR CALLING CARD FOR A BRILLIANT FUTURE...

Bendix Missile Section is a major contractor in the U.S. Navy's guided missile program—a part of the "new look" in our defense plan. Our expanding program has many opportunities for quality control personnel: *Reliability Engineers, Quality Control Analysts, Statisticians,* and *Operations Research Specialists* will find challenging assignments in breaking through reliability barriers. Take time now to look into the opportunities which Bendix can offer you.

Write Employment Dept. M., 401 Bendix Drive, South Bend, Indiana.

"We find Norton discs outproduced others—2 to 1"

One of many job reports showing how Norton discs add the profit-boosting "TOUCH of GOLD"

MORE OF THE SAME:

- "Norton discs the best ever received. Produced over 6,000,000 piston rings — 100% more than our former discs, with 50% less dressing. Results duplicated in subsequent shipments."
- "Outlasted and outperformed all other discs. Gave 366,975 pieces without burn."
- "Averaged 21,500 pieces, a new high for this job."
- "High above competition for output and grinding quality."
- "Gave 20% longer service life."

What Norton discs have done for others, they can do for you.

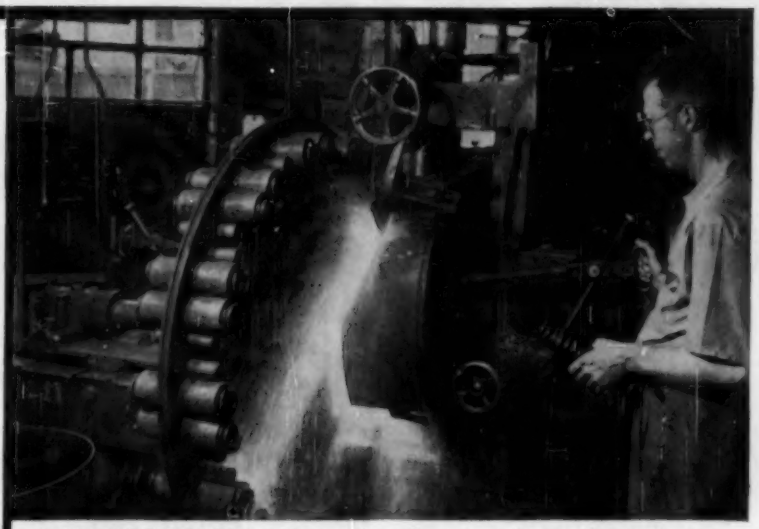
That goes for any material you're grinding, on any type of disc grinding machine.

Norton discs of ALUNDUM* and CRYSTOLON* abrasives are made in all standard grit sizes, all grinding grades, five types of bonds and all types of mountings. They are precision-built for closest uniformity — so you can depend on the same cool cutting action and extra long service life every time you re-order.

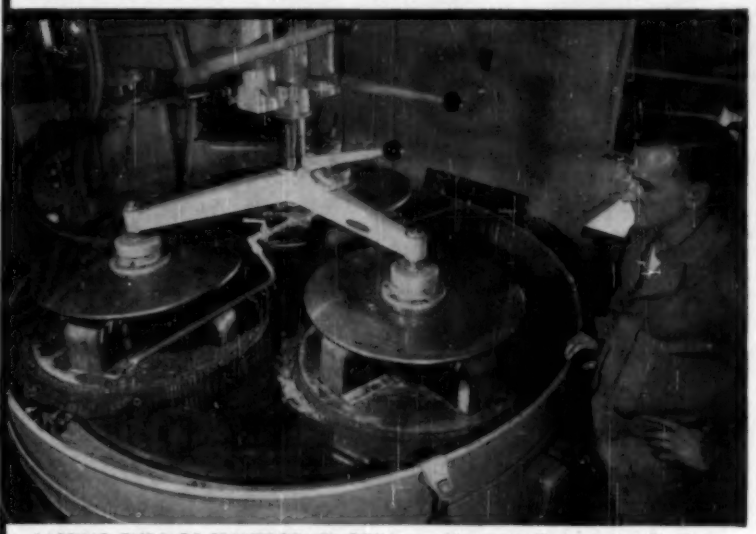
See Your Norton Distributor

for valuable aid in selecting the right discs for your jobs. Ask him for the booklet, *Disc Grinding*. Or write to the nearest district office of NORTON COMPANY, Worcester 6, Mass. Distributors in all industrial areas, listed under "Grinding Wheels" in your phone book, yellow pages. Behr-Manning Company, Troy, N. Y., division of Norton Company. *Export:* Norton Behr-Manning Overseas Incorporated, Worcester 6, Mass.

W-1725



HEAVY STOCK REMOVAL with precision tolerance on this double spindle disc grinder is a faster, easier job when a Norton disc adds the "Touch of Gold." Norton covers the entire range of disc grinding applications, from snagging to lapping.



LAPPING ENDS OF TRANSFORMER COILS on a Norton 60-F HYPRO-LAP* lapping machine equipped with a Norton disc. Only Norton offers you such long experience in both grinding wheels and grinding machines to help you produce more at lower cost.

NORTON
ABRASIVES

Making better products... to make your products better

NORTON PRODUCTS: Abrasives • Grinding Wheels • Grinding Machines • Refractories
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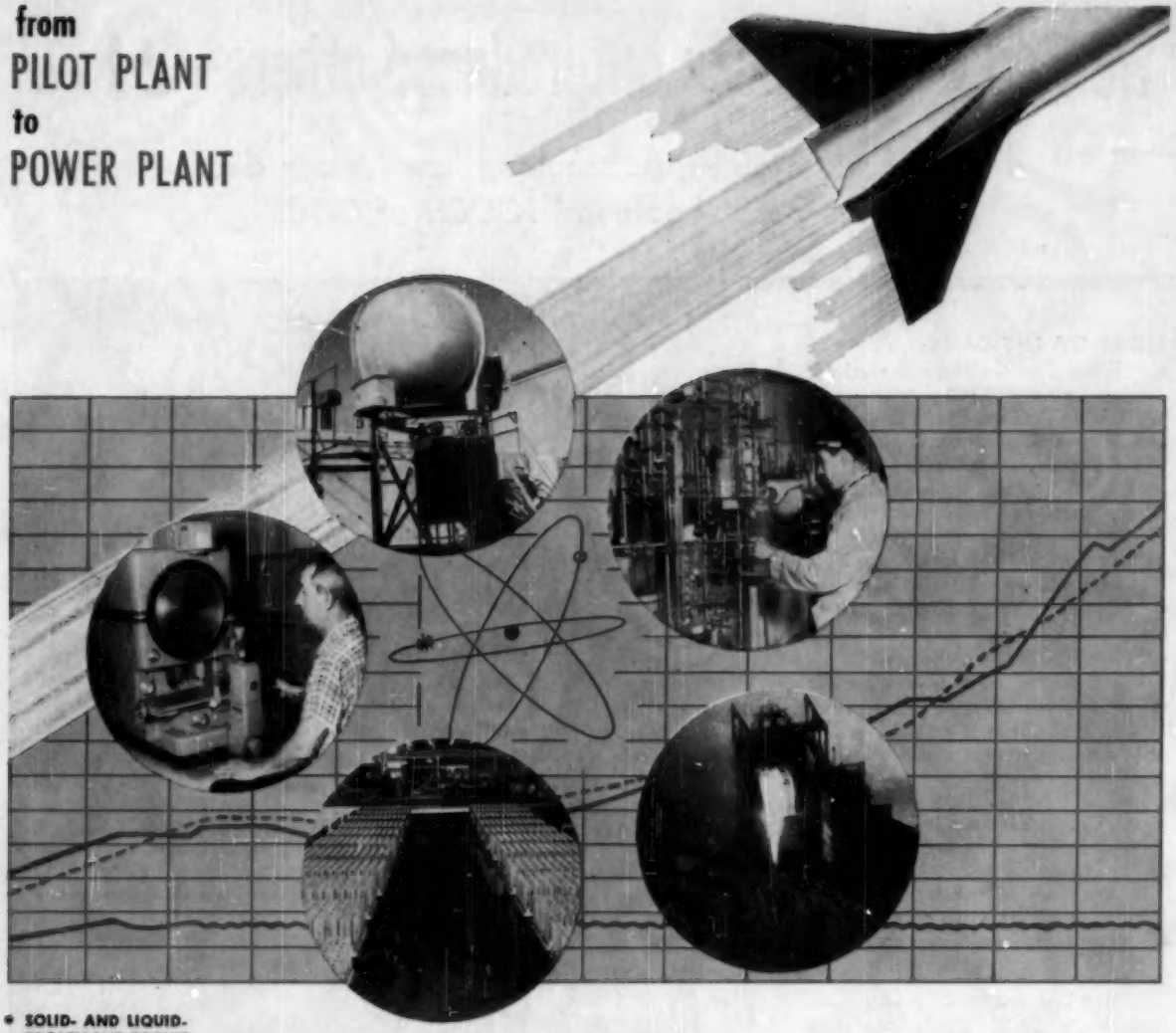
*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries

EUGENE B POWER
UNIV MICROFILMS
313 N FIRST ST
ANN ARBOR MICH

from PILOT PLANT to POWER PLANT



- SOLID- AND LIQUID-PROPELLANT ROCKET POWERPLANTS FOR MISSILE AND AIRCRAFT APPLICATIONS
- AEROBRAKE THRUST REVERSER (SNECMA)
- AUXILIARY POWER UNITS AND GAS GENERATORS
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- UNDERWATER PROPULSION DEVICES
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QUALITY CONTROL FOR ROCKET ENGINE RELIABILITY

Today, as never before, rocket power is a dominant military requirement. Aerojet-General propulsion devices are used from Pole to Equator. They must operate with the flick of a switch at any altitude, any attitude, over extreme temperature ranges.

But the price of optimum reliability is maximum vigilance. At Aerojet, this means the uncompromising control of every characteristic of every engine, every component in research, development and production.

There are no short cuts to certainty. Aerojet uses all the techniques of modern quality programs — new-design control, acceptance sampling plans, statistical analysis, quality auditing. In actual test-firings of complete rocket systems, Aerojet has spent over six million man-hours since 1942.

The results are unique in the rocket propulsion field: *Aerojet products in field use have an overall measured reliability of 99.6%.*

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QUALITY CONTROL ENGINEERS

Aerojet-General CORPORATION

A Subsidiary of The General Tire & Rubber Company

THE GENERAL TIRE

AZUSA, CALIFORNIA
SACRAMENTO, CALIFORNIA

MORE POWER FOR AIR POWER